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The Franklin Institute

1826

1957

Organizing for Effective Air Pollution Control
EDWARD R. WEIDLEIN

Electromagnetic Radiation from Lightning Strokes
E. L. HILL

From Imbibition to Exhibition
EDWIN H. LAND

The Magneto-Ionic Expander Isotope Separator
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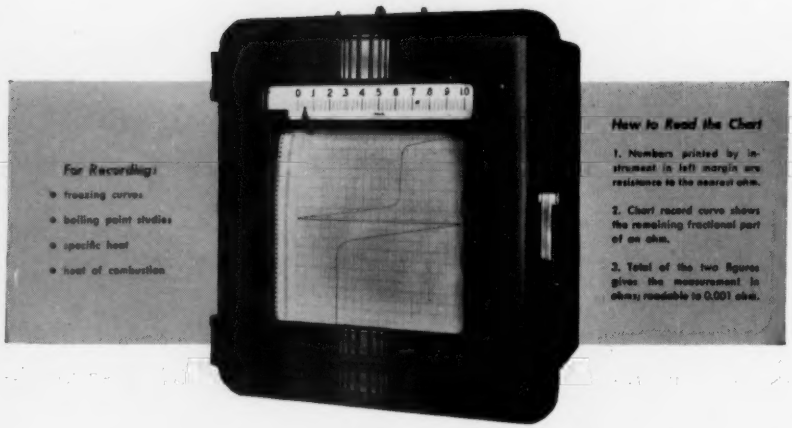
Franklin Institute:
Research Notes
Department Reports
Book Reviews
Current Topics
NBS Notes

VOL. 263 NO. 2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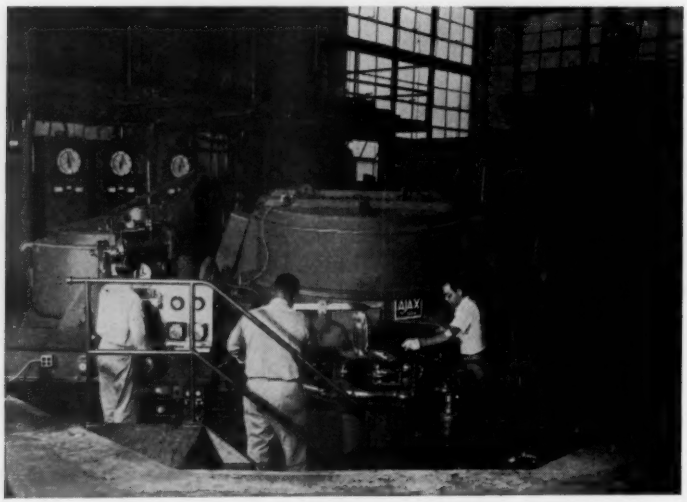

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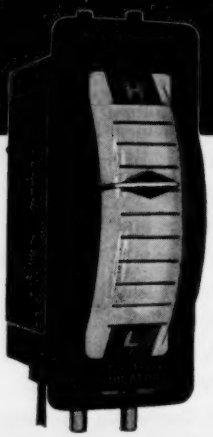

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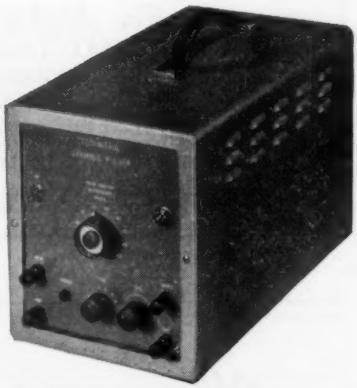

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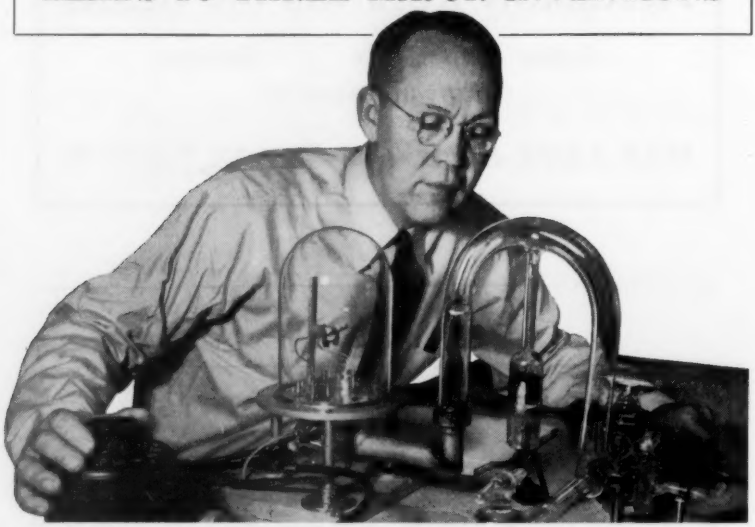
New technique shapes future of transistors... LEADS TO THREE MAJOR INVENTIONS



Calvin S. Fuller, Ph.D. in Physical Chemistry from the University of Chicago, is a pioneer in development of the diffusion technique. Here he controls a heating current through a strip of silicon while diffusing into its surface a film of aluminum less than 1/50th of a hair's breadth in thickness.

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The diffusion technique opened the way to three major Bell Laboratories inventions in the semiconductor field: the Bell Solar Battery, Silicon Power Rectifier and the Diffused Base Transistor. Right now the technique is providing a key to many other developments of great promise for telephony. It is another example of how Bell Labs works to improve telephony through fundamental research in materials.

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The Francis J. Clamer Medal (1943—Silver Medal).—This medal is awarded at least once in five years for meritorious achievement in the field of Metallurgy.

The Stuart Ballantine Medal (1946—Gold Medal).—This medal is to be awarded in recognition of outstanding achievement in the fields of Communication and Reconnaissance which employ electromagnetic radiation.

The Boyden Premium (1859).—This premium is awarded not oftener than once in five years to any resident of North America who has recently made a notable experimental determination of the speed, in free space, of radiation in any region of the entire spectrum.

The William M. Vermilye Medal (1937—Bronze Medal).—This medal is awarded not oftener than biennially in recognition of outstanding contribution in the field of Industrial Management.

The Certificate of Merit (1882).—A Certificate of Merit is awarded to persons adjudged worthy thereof for meritorious inventions, discoveries or improvements in physical processes or devices.

For further information relating to these awards apply to the Secretary, Committee on Science and the Arts

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Vol. 263 FEBRUARY, 1957 No. 2

ORGANIZING FOR EFFECTIVE AIR POLLUTION CONTROL *

BY

EDWARD R. WEIDLEIN [1]

Cleaner Air Week is now being observed nationally and has won the endorsement of civic, governmental and industrial leaders throughout the nation. People are becoming seriously interested in the air they breathe. It is timely that greater emphasis should be placed on the occasion of the seventh annual observance of "Cleaner Air Week," and that the sponsor of this drive is the Air Pollution Control Association. It is an educational program to bring home the fact that every element of community life adds pollution to the atmosphere. This includes the home owner burning refuse or making faulty use of fuels or combustion equipment, the motor vehicle with its exhaust, the factory with its furnaces or chemical processes and a great many other activities which emit dust or tiny particles of solid matter. I just recently visited a small town in Kansas, 6000 population, that is enforcing an air pollution control program, which outlaws all backyard incinerators, burning of waste and has installed a garbage and waste collection system. Here is a community that is not bothered with air inversions or congested traffic and usually has plenty of wind to blow away the fumes but still realizes that air can become contaminated if not carefully guarded.

It is likewise important that everyone in the community knows the tremendous amount of work already accomplished through research and the application of controls. Air pollution control is being made more effective through industry committees organized by APCA, whereby all the knowledge gained in any particular industry, such as steel, oil, chemical or heating equipment, can be pooled for the benefit of the industry as a whole. The team approach is stressed by APCA. Labor

* Talk given during Cleaner Air Week in Philadelphia, Pa., at The Franklin Institute, October 22, 1956.

[1] Chairman, Smoke Control Advisory Committee, Pittsburgh, Pa.; formerly, President, Mellon Institute, Pittsburgh, Pa.

(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors in the JOURNAL.

unions, government, housewives, industry, construction, transportation and the professions have related interests in air pollution control. All segments of the community must work together for cleaner air, our most precious resource.

I have selected as my subject *Organizing for Effective Air Pollution Control* and will use the City of Pittsburgh merely as an example to show what can be accomplished by a united community. Almost everyone in the world regarded Pittsburgh as the "Smoky City," and when they visit us today they are amazed at what has been accomplished. We are not content, however, with our achievements. The ordinances call for constant research and development work, and every year we expect additional improvements in the air we breathe.

One of the most complete investigations on the air pollution problem was carried out by Mellon Institute from 1911 to 1914, and the nine bulletins published by this investigation are still regarded as the fundamental basis for drawing up ordinances to control air pollution. These bulletins covered every phase of the air pollution problem, such as the economic, psychological, meteorological, engineering, and the effect on health and vegetation. The automobile is the only new problem that has entered the picture. If you change the dates and read the bulletins, you will obtain the same situation in most cities today that existed when the investigation was made. To quote from one of the publications, "The story of the smoke nuisance is the old and oft-told story which runs through the history of American municipalities. It is the story of rapid growth in population and industrial activity, marked by wastefulness of natural resources, carelessness in regard to the future, indifference to many of the precious things of life, and a blind opposition toward anything which seems to threaten in even a remote way that which is termed 'prosperity.'"

The first reference to the smoke problem in Pittsburgh was a letter to Council dated June 10, 1804, as follows: "I would be extremely sorry to be in any way the means of subjecting any of our fellow citizens to unnecessary or useless expense, but in this instance not only the comfort, health and, in some measures, the consequence of the place, but the peace and harmony of the inhabitants depend upon the speedy measures being adopted to remedy the nuisance." This was the beginning of the first legislation to control air pollution in the city of Pittsburgh, and many ordinances have been passed since that date. However, to illustrate law ineffectiveness, the Ordinance passed in 1869, Section 2344, reads: "No bituminous coal or wood shall be used in the engine or any locomotive employed in conducting trains upon any railroad." This is a good illustration of how not to write an effective ordinance, as the Pittsburgh and Allegheny County ordinances in effect today do not contain a single item that one cannot enforce; and the provisions are made to carry out research to try to find the answers to unsolved

problems. Just as soon as an answer is obtained, the ordinance is modified to eliminate the nuisance. The mere enactment of a reasonable, efficient and enforceable smoke ordinance is not enough. The ordinance must be enforced. At this point most of the cities have fallen short. Sometimes the wrong methods are used in the enforcement of the ordinance. Most of the time the methods employed are altogether too lax and feeble to secure even mediocre results.

To remedy this situation there is one great weapon—public opinion. In order to educate, concentrate and focus public opinion, however, it requires an organization that can bring every phase of the community under one central body. In Pittsburgh we have such a cooperative group in the Allegheny Conference on Community Development. The Allegheny Conference was formed in the war years to achieve unity of action in the community. It is a citizens' nonprofit organization, enlisting the full strength and best talents of industry, public administration, education, finance, science, and the agencies of public opinion. Its one objective is to develop the material and human resources of the region where the Conference works and to make secure that region's future. It is founded on a fresh concept of modern community life—the concept of people living together in productive enterprise, rewarded in terms of work and enjoyment. The Conference does not impose—it unites.

The Allegheny Conference can recommend. It cannot enact. For the exercise of the power of government, a community must look to its elected officials who are given the responsibility of legislation and administration.

The civic program for Pittsburgh can go forward only with the help of the peoples' representatives. That help has come unstintingly from the Governor of the State, from the Mayor of the City, and from the County Commissioners.

Party differences have been submerged in community betterment. Legislative bodies such as the General Assembly, Pittsburgh City Council, and Allegheny County Commissioners have created the implements of progress. As citizens we have cause to be grateful. Courageous and capable public administration is essential to public betterment.

In a sense the Smoke Control Bureaus of Pittsburgh and Allegheny County are really a part of the Conference activities, although they report to and are paid by our respective tax supported governments.

The Equitable Life Assurance Society was approached to invest its funds in office buildings in what is now known as the Gateway Center. This company asked two questions: (1) What are you doing about your smoke? and (2) What are you doing about your floods? When it was given satisfactory answers to these two questions, it decided to come to Pittsburgh.

The City of Pittsburgh and Allegheny County are on the way to

being the cleanest industrial community in the country. Today people want to live in clean, healthy surroundings, free from smogs and smoke, where skies are bright and clear and there is plenty of sunshine. This is being accomplished, after 150 years of laws and ordinances, in a period of nine years, and for two reasons: first, solid backing from industry and the community; second, and just as important a reason, air pollution control in Pittsburgh has been taken completely out of politics.

One other important factor is the tendency in some quarters to endeavor to have legislation passed at the state level that will cover the entire state and will be controlled at that level of government. It is my considered opinion that such an approach will not be practical because each locality has its own peculiarities. It will further be hamstrung by political manipulation and conflict of interest between the authorities at the state level and those at the local city and municipal level. The existing physical boundaries of Allegheny County present a reasonable area for the administration of such regulations.

A smoke control ordinance has been in full effect in the City of Pittsburgh since October 1, 1947. It has already produced remarkable results in the City's atmosphere. The City Ordinance is based on state enabling legislation passed in 1911. The Ordinance was enacted by the City Council in 1941, but its enforcement was postponed because of the war. At the close of the war the United Smoke Council, an organization that has been interested in smoke abatement for many years and now is a part of the Allegheny Conference program, recommended that the provisions of the Ordinance be made fully effective. On October 1, 1946, industry and railroads were brought under control and a year later, October 1, 1947, the households were included, making the Ordinance fully effective. On May 28, 1943, the State Legislature had passed enabling legislation permitting the Board of County Commissioners of Allegheny County to regulate smoke from all sources "except railroad locomotives." That act reads as follows: "Authorizing counties of the second class to regulate the production of smoke from chimneys, smokestacks or other sources, including provisions for the payment of inspection and certificates of compliance fees incident thereto; authorizing the expenditure of money for the employment of persons, and the acquisition of property for effectuating such regulations; and providing penalities for the violation thereof."

At a meeting of borough and township officials called by the Board of Commissioners in November, 1946, the majority expressed themselves in favor of a County-wide smoke control program and recommended the inclusion of railroads in any such program. At this meeting petitions signed by more than 48,000 voters of Allegheny County favoring County-wide smoke regulations were presented. In the 1947 session of the State Legislature, the Fleming-Barrett amendment,

empowering the County Commissioners to regulate smoke from all sources, including railroad locomotives, was overwhelmingly adopted.

The Board of Commissioners of Allegheny County enacted a County Smoke Control Ordinance effective June 1, 1949. Industry was brought under control first, giving the householder a four-year grace period in which to arrange for smokeless heating. This grace period expired June 1, 1953.

The ordinances under which the city and county bureaus operate are similar but contain two striking differences:

(*a*) The city's ordinance regulates noxious acids, fumes, and gases; the county ordinance does not.

(*b*) The county ordinance spells out in detail requirements for the various types of industrial fuel burning equipment; the city ordinance does not.

While the city bureau's jurisdiction is much more heavily built up, the county's jurisdiction is approximately twelve times as large and extends over 129 separate political subdivisions.

Both are concerned with the regulation of smoke emission from all types of combustion chambers including residential installations, incinerators, open fires, such as the burning of upholstery and other materials from scrap automobile bodies, locomotives, river boats, commercial buildings and industries.

The Allegheny Country Bureau of Smoke Control feels that, next to the atmospheric pollution created by industry, the second largest individual contributor could be the promiscuous installation of rubbish and garbage consuming incinerators of improper design. A properly designed domestic incinerator still requires extensive research. Well designed industrial incinerators have proved themselves "good neighbors."

The County embraces an area of approximately 700 square miles and a population of 1,548,500 people. In it is concentrated a steel ingot capacity of almost 13,000,000 tons per year which is more than one-half of the peak war-time capacity of all the steel industries of Germany. Furthermore, we enjoy a concentration of connected horsepower that is the greatest in the country. Speaking more specifically, we have approximately 100 open hearth furnaces; 29 blast furnaces; a number of puddling furnaces and bessemer converters; one of the largest cement mills in the country using the dry process, and several others using the wet process; two large by-product coke plants; brick kilns; paint works; chemical works; oil refineries; and a large assortment of miscellaneous industries, such as Westinghouse Electric Corporation, Westinghouse Air Brake Company, Dravo Corporation (ship yards), Pittsburgh Screw and Bolt Company, not to mention railroads handling the largest tonnage for any community in the country.

The second largest industry in the area is, of course, bituminous coal

mining. Every mine or coal preparation plant has its gob piles. A large burning gob pile is capable of polluting the atmosphere for miles to leeward with a very disagreeable haze which under damp weather conditions may become irritating to the nasal tract. Chief gases emitted by these piles are CO, CO_2, SO_2 and H_2S. There was no known practical economical method for extinguishing them or for preventing ignition of dormant piles. Some of these piles have been burning for fifty years and this was included in the Ordinance as a research problem, which was supported by the coal industry, to find an economical and satisfactory method of extinguishing the fires and to so construct the piles in the future as to prevent combustion. This has been satisfactorily solved, and is now included in the new Ordinance.

One question will immediately come to your mind, that is, do we have fogs and air inversion? The answer is "yes," we have them on an average of 300 days per year, and the Donora catastrophe in October, 1948, the second worst in the world, was the final spark to make the average citizen realize that he had a part in the air pollution control program. Pittsburgh is surrounded by hills, and the two rivers that come together at the Point to form the Ohio are ideal for the formation of fogs. We still have fogs but they are now light in color and usually lift by midmorning, where formerly they were so dense that they produced a night effect and hung on for days, because of the fumes, smoke, and dust particles mixed with the fog. Recently during the Christmas holidays our airport was overcrowded with planes that could not land, owing to atmospheric pollution, at any eastern airport or midwestern airport. You can imagine the pride of our local newspapers which made valuable capital out of this situation, and I would like to add that our newspapers have had a great deal to do with the success of our program. In fact, without their support we would not have been able to maintain the enthusiastic cooperation of the citizens.

The question was how to draft a realistic smoke abatement ordinance that could be enforced immediately and improved upon through constant research. No single individual could have such a broad knowledge of the various problems involved that he could be entrusted with the drawing up of such a document and we also realized that no one man could administer such an ordinance without help from others. With this understanding, the Board of County Commissioners requested recommendations for membership in an advisory committee from civic groups throughout the county. As a result a seventeen man committee was appointed under my chairmanship. This committee—known as the Smoke Control Advisory Committee, serving without pay—is a broad cross-section of Allegheny County, consisting of the presidents of several of our largest corporations, the operating vice president of one of our railroads, the president of the local United Mine Workers, the president of a Teamsters' Union, the mayor of one of our third class

cities who also is a CIO representative, the editor of the negro newspaper, the president of the Congress of Women's Clubs, the chairman of the Smoke Committee of the Chamber of Commerce, the executive secretary of the Retail Coal Merchants' Association, etc.

Even with such an advisory committee none had the knowledge or the time to do the detailed work. Subcommittees were necessary, again to serve without compensation. To begin with, four subcommittees were appointed.

1. Steel and Allied Industries—chairman, the President of United States Steel Corporation; co-chairman, Assistant Chief Engineer of United States Steel Corporation.

2. Railroads—chairman, Operating Vice President of Pittsburgh and Lake Erie Railroad (New York Central System); co-chairman, Assistant General Manager of the Pennsylvania Railroad.

3. Power and Heating Plants—chairman, President of Jones & Laughlin Steel Corporation; co-chairman, General Superintendent of Power Stations of Duquesne Light Company.

4. Miscellaneous Industries—chairman, Vice President of Union Barge Lines.

All of the above chairmen wrote or personally called on the industries under their jurisdiction asking for engineering talent to make up their technical subcommittees. For instance, the Railroad Subcommittee membership was made up of the Superintendents of Motive Power (or equivalent title) of all the railroads operating in the county. The Steel Subcommittee was made up of the Chief Engineers or Assistant Chief Engineers, sometimes Vice Presidents in Charge of Engineering, of the majority of the steel companies in the county. On the Power and Heating Plant Subcommittee there were Chief Plant Engineers of such industries as: A. M. Byers Company, H. J. Heinz Company, Westinghouse Electric Corporation, West Penn Power Company, etc. All these subcommittees gave unstintingly of their time and effort looking to the drawing up of the various Articles which constitute the Ordinance. It was most interesting to note as I sat in the meetings of the various subcommittees how very little selfish interest and how very much citizenship were manifest in the operations of the subcommittees.

This entire process of constructing the County Ordinance required a period of eighteen months. At first the main advisory committee met only about once every two months. However, beginning the last of July of 1948 the main advisory committee met semi-monthly and carefully considered, at sessions lasting approximately three hours, the progress reports of the various subcommittees. Needless to say many heated discussions arose and differences of opinions were ironed out. But there was never the slightest indication of any animosity and at the final meeting when the completed Ordinance was presented to the

Advisory Committee for approval, it was unanimously adopted. This was an achievement beyond anyone's expectations, when it is better understood what such an ordinance would cost the Pittsburgh district. Pittsburgh's prosperity depends upon its coal and steel, and yet the very men representing labor and industry on the committee were willing to commit their respective unions and industries to a program that would greatly reduce the amount of coal that would be consumed in the district, and would cost the industries many millions of dollars to comply with the new ordinance. The home owner likewise would be required to pay increased costs for heating by using 50 per cent low volatile fuel with bituminous coal, or installing new equipment such as special smokeless stoves, stokers or converting to gas or oil. Everyone had a part in the program—labor, industry, the merchant and the private citizen—and therefore it definitely became a community enterprise.

Having drawn up the main portion of the Ordinance, the next question was that of fees. We had on the Advisory Committee an expert on tax problems who thoroughly knew the industrial situation of the district and yet did not have any self-seeking industrial axe to grind. He was made chairman of the Fees Subcommittee, the remainder of the subcommittee being made up of the chairmen and the co-chairmen of the four subcommittees mentioned earlier. Very careful studies were made by the chairman of this subcommittee and his economists of a number of different bases on which fees could be charged. In several instances we came to the conclusion that, while we could build up a very nice "take" for the Office of Smoke Abatement in terms of dollars, this would cost us $2.00 for every $1.00 taken in. In other words, the theory of diminishing returns loomed very large. As a result no effort was made to make the office self-supporting or even semi self-supporting, but to make it a service department to the public as a whole. The receipts do not average more than 15 per cent of the budget of the office. The remainder comes from the taxpayers. The subcommittee further felt that this was right and proper, that all citizens profit from the activity and therefore all taxpayers should foot the bill. The cost of operating the County budget for 1955 was $55,000, and the cost of the City bureau was $88,000.

The railroads and the steel industry provide their own inspectors and the County and City employ engineers who render service rather than merely inspection.

Also, I would like to state that no monies were raised for developing the whole program and all research activities demanded by the Ordinance are or will be paid for by the specific industries required to do such work to meet the Ordinance.

I think it is of interest to point out that by and large the Ordinance was drawn up by engineers. There was not a single lawyer on any of the advisory committees, and, while there was one member of the

Advisory Committee who might be termed a politician, he attended only two meetings and at such meetings took no active part. The only contact that the Ordinance had with the legal profession was its review by the County Legal Department which resulted in a modification of the language but in no change whatsoever in the intent of the draft. In this connection I would like to emphasize further that the executives, particularly of industry, made it a point to be present at all the meetings of the Advisory Committee unless they were unavoidably out of town. I know of certain of these executives who postponed out of town business engagements in order to attend the meetings.

The spirit of cooperation in the subcommittees as well as in the main Advisory Committee was of such a nature that it was possible for me, largely by the power of suggestion, to have written into the Ordinance sections definitely pointing the finger at sources of air pollution for which problems no practical or economical solution at present existed, but which indicated the necessity for research programs looking toward a successful outcome. Among these studies may be mentioned the reduction of cinders from steam locomotives, the control of emissions from the bessemer converters and the open hearth furnaces, and scientific and engineering research to attack the gob pile menace.

I have already pointed out that the gob pile problem has been solved. The elimination of fly ash has likewise been corrected due to the fact that the railroads as well as the river boats are 100 per cent dieselized.

Diesel engines have been brought under supervision and control by the new Ordinance, and this I believe is the first time such a regulation has been included in any law. Diesel engines, if they are properly maintained, properly serviced and properly driven, need not emit smoke. For the first time they are now permitted to be used in Pennsylvania for underground coal mining.

Under the laws of the Commonwealth of Pennsylvania counties may only exercise such powers as are delegated to them by the State Legislature. The enabling act empowers the County to "abate smoke." You will, therefore, find the standard nuisance clause deleted from this Ordinance and the control of gases, etc. is only approached indirectly. We feel that we have stretched the smoke control act just as far as we dared under the terms of our enabling act. Were it not for public opinion, perhaps we would not have extended it as far as we have. It is my firm hope and conviction that, in the not far distant future, the State Legislature can be prevailed upon to amend our present act to call for the control of air pollution rather than abatement of smoke.

Industry has already achieved an impressive and remarkable record here in advancing smoke abatement, having spent more than $200,000,000 in Pittsburgh and Allegheny County to conform to the smoke control ordinances. More than half this amount has been spent in the County outside the city limits. The control of atmospheric

pollution in the city and county is solely for the benefit of the individual citizen; however industry has received some financial returns.

The installation of modern combustion equipment, dust collectors, new boiler plants, gas cleaning and washing equipment, precipitators, diesel locomotives and river boats and other scientific methods and devices are contributing immensely to the elimination, reduction and control of smoke and other pollutants.

And this is taking place in one of the world's greatest centers of heavy industry that consumes annually about 50,000,000 tons of coal.

Extensive research programs going far beyond smoke abatement and aimed at the elimination and control of air pollution of all kinds are being carried on by industry.

The industry committees have just recently completed a revision of the Ordinance, tightening it up all along the line so far as industry is concerned, applying the knowledge that has been gained during the grace period provided in the Ordinance. We now have a better and stronger Ordinance under which industry has to live and you can see the Advisory Committee is still functioning.

Smogs that once blackened the city are gone. The air is much cleaner. There is more sunlight. Curtains, linens, and clothing stay fresh longer. Cleaner living conditions have saved city residents an estimated $27,000,000 annually or $41.00 each in laundry and cleaning bills, household expenses and other economies.

But, with all the scientific research and engineering progress that were made during the past fifty years, the problem would still be unsolved without the backing of an enlightened public and enlightened public officials.

ELECTROMAGNETIC RADIATION FROM LIGHTNING STROKES *

BY

E. L. HILL [1]

SUMMARY

A theory is given of the spectral distribution and the absolute amount of low frequency electromagnetic radiation emitted from a vertical lightning stroke from cloud to ground. The calculation depends on an assumed physical mechanism for the flow of charge on the discharge channel, but the model corresponds closely to the empirical observations of Schonland, Pierce, and others. The radiated energy has a maximum intensity at about 11 kc/sec and a total width at half-maximum of 12 kc/sec. The predicted radiation in the megacycle region agrees reasonably well with that reported by Chandrashekhar Aiya, although the present theory was developed primarily for the low frequency region. The total energy radiated in one leader and return stroke is estimated to be about 220,000 joules.

I. INTRODUCTION

The erratic occurrence of natural lightning makes it very difficult to obtain absolute measurements of the electromagnetic energy which is radiated. The total radiation and its spectral distribution also may vary widely from stroke to stroke. Laby and his co-workers (1)[2] have made measurements of waveforms of atmospherics in Australia from which they estimate the mean radiated energy per stroke to be of the order of 2×10^5 joules. This figure may be different in other regions, depending on the prevalent type of storm.

Extensive statistical studies have been made on the noise power spectrum. The low frequency noise has been discussed recently by Barlow, Frey, and Newman (2), while the high frequency region (1 Mc to 20 Mc) has been studied by Chandrashekhar Aiya (3). These papers give references to other important recent work.

Much of our knowledge of the mechanism of natural lightning is derived from measurements in the visual optical region, from quasi-static changes in the field of a thundercloud during a storm, and from the analysis of waveforms of atmospherics. Most of the theoretical work has been based on the approximation of the field of a thundercloud by a variable electrical dipole, with dependence on measured waveforms to provide a spectrum analysis of the radiation (4).

The work reported in this paper has been prompted by a desire to

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[2] The boldface numbers in parentheses refer to the references appended to this paper.

make a theoretical analysis of the radiated energy directly from the physical mechanisms governing the discharge. Such a procedure is a little hazardous in that some of the pertinent features of the discharge can only be guessed at under present circumstances. Nevertheless, our understanding of the mechanism of the lightning stroke seems to have progressed to a point at which a theoretical study in absolute terms should be helpful in identifying some of the factors which tend to be hidden in more formal phenomenological discussions.

Our aim is to start with a model of a vertical cloud-ground stroke which has been derived largely from a consideration of the experimental work of Schonland, Pierce, Norinder, and others, and to estimate the radiated energy by use of Maxwell's field equations. Particular emphasis is laid on the low frequency region since the main interest at present is in radio interference problems.

2. THE MODEL OF A VERTICAL LIGHTNING STROKE

The early work of Norinder (5) showed that the main processes in a lightning stroke are aperiodic. The detailed studies by C. T. R. Wilson, Schonland, and many other workers have made it possible to develop a fairly precise picture of the physical mechanisms which are operative in the discharge (6).

The major components of a single lightning stroke to ground are the leader and the return stroke. The former is known to be complex, possibly including an initial pilot streamer. The leader stroke itself proceeds in the formation of an ionized channel by a succession of steps, often with the establishment of many side branches. After the leader makes contact with the ground it is followed by the return stroke which proceeds up the pre-formed channel at a speed which is much higher than the mean speed of the downward leader. There is evidence that the return stroke diminishes in speed as it moves up the channel but the exact manner in which this takes place is yet in doubt.

It would be unprofitable to try to take all of the complications in a stroke into account in this preliminary study of the radiation. We shall make the simplification that both the leader and the return stroke travel with constant speeds. This probably underestimates the radiation from the individual steps of the leader stroke and possibly overestimates that from the return stroke. It is not apparent that the estimate of the total radiated energy should be falsified greatly, although there may be some error in the computed power spectrum. The smoothing effect of this assumption would be expected to be most evident in the prediction of radiated waveforms which we do not undertake in this paper.

Attention will be concentrated on the radiation coming from the exterior channel of the stroke; that is, on the part of the discharge between the cloud base and the ground. The term "cloud base" is

itself somewhat indefinite in meaning and its use emphasizes our present ignorance of the details of the motions of the electrical charges within the body of a thundercloud during a stroke. This is possibly a serious point since we have no way at present of determining the magnitude of the contribution of the distributed currents in and above the cloud to the radiated energy. The best compromise which can be made is to consider the length of the discharge channel as an adjustable parameter.

In order to calculate the radiation in the long wavelength part of the spectrum, in which the wavelength of the radiation is large compared with the length of the channel, one must have some picture of the coherent flow of current over the channel as a whole. We idealize the cloud base and the earth as parallel conducting planes having a separation h, the former being negatively charged to a potential $V_c = -Eh$

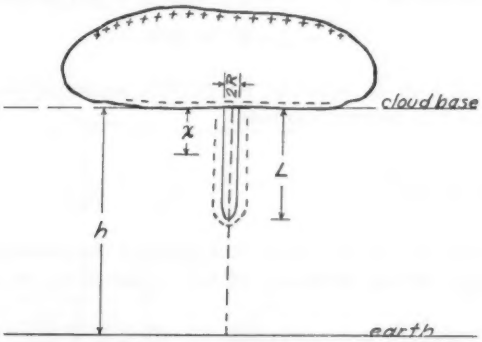

FIG. 1. Schematic diagram of the development of the ionized channel by the leader stroke.

with respect to the ground. The electric field is then directed from the ground to the cloud and is of magnitude E (volts/meter). The ionized channel of the stroke at any stage of its development will be idealized as a thin elongated spheroidal surface of base $2R$ on the cloud base, and of length L. These geometrical conditions are indicated schematically in Fig. 1.

Since the ionized channel of the developing stroke will be partially conducting, and since it is subject to the general electric field between the cloud and the earth, there must be a flow of charge from the cloud tending to make the channel an equipotential region. We think of this as leading to a quasi-static charge distribution on the surface of the channel.

When the leader stroke reaches the ground the ionized channel becomes a short-circuiting path between cloud and ground. It is difficult to decide on *a priori* grounds what physical processes will be associated with the return stroke, but in any event there should occur

a current flow which tends to remove the excess negative charge deposited on the channel during the development of the leader stroke. We assume that this is the main consequence of the return stroke so far as the radiation is concerned. The current associated with the return stroke is equivalent to a surge of positive charge from the ground up the channel.

The charge distribution on the channel during the development of the leader stroke can be estimated from the corresponding electrostatic problem of a conducting spheroid on a plane in a uniform field (7). With the notation indicated in Fig. 1 the charge/meter on the channel at a distance x from the cloud base is given by the expression

$$q(x,L) = -\frac{2\pi\epsilon_v Ex}{\eta_0^2(\eta_0 \coth^{-1}\eta_0 - 1)}, \qquad (0 \leqslant x \leqslant L) \tag{1}$$

where

$$\eta_0 = L/(L^2 - R^2)^{\frac{1}{2}}. \tag{2}$$

Since $R/L \ll 1$ it is feasible to permit some approximations in Eq. 1. One has the series expansion

$$\eta_0^2(\eta_0 \coth^{-1}\eta_0 - 1) = \frac{1}{3} + \frac{1}{5\eta_0^2} + \frac{1}{7\eta_0^4} + \cdots, \tag{3}$$

which is valid for $|\eta_0| > 1$. Since it is beyond the power of the present theory to give a precise estimate of the value of η_0 we replace Eq. 1 by the form

$$q(x,L) = -\alpha 6\pi\epsilon_v Ex. \qquad (0 \leqslant x \leqslant L) \tag{4}$$

This form is obtained by using only the first term in the series of Eq. 3, but with the introduction of an empirical parameter, α, to allow for some adjustment in the absolute magnitude of the charge on the channel by comparison with empirical data. The value of this parameter is expected to be near unity and it will be shown later that this is in good agreement with the experimental results. The treatment of α as independent of L is made plausible by the physical argument that the diameter of the channel probably increases somewhat as the discharge progresses. The actual charge on the channel is expected to be appreciably smaller than would be indicated by a strict application of the electrostatic approximation since the channel will not be perfectly conducting and the charge collection mechanism in the cloud is not perfect.

The total charge on the channel is found from Eq. 4 to be

$$Q(L) = \int_0^L q(x,L)\,dx = -3\pi\alpha\epsilon_v EL^2, \tag{5}$$

from which the current flow at the base of the channel is found to be

$$|I(L,t)| = |dQ/dt| = 6\pi a\epsilon_v EL \cdot dL/dt. \tag{6}$$

Here we can interpret $v_l = dL/dt$ as the mean speed of the leader stroke.

These formulas are expected to hold from time $t = 0$, when the leader starts from the cloud base, until $t_l = h/v_l$ when it reaches the ground. At the instant t_l the current along the whole channel has the maximum value which it attains during the leader stroke

$$|I(h,t_l)| = 6\pi a\epsilon_v Ehv_l. \tag{7}$$

The characteristics of the return stroke are much more difficult to assess. For lack of better evidence we assume that the inertia of the magnetic field associated with the leader stroke current maintains the current given in Eq. 7 at any point on the channel until the arrival

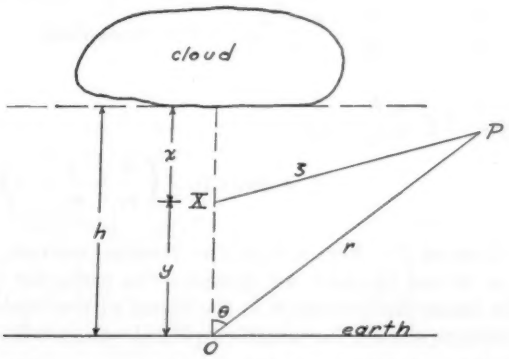

FIG. 2. Geometrical coordinates for the calculation of the radiation at the distant point P.

of the return stroke at that point. The following assumptions concerning the current in the return stroke do not seem to be unreasonable on physical grounds. When the return stroke reaches a point on the channel it is just such as, (*a*) to annihilate the current remaining from the leader stroke, (*b*) to remove the charge on the channel at the rate of progress of the return stroke, and (*c*) to provide a residual current I_f which continues to flow in the channel for some time after the return stroke has passed. The last contribution is inserted because it is known that after the return stroke is over there remains a low residual current which may last for a relatively long time and which is responsible for transporting the bulk of the electrical charge which passes in the stroke. The contribution of this residual current to the radiated energy is expected to be negligible. The radiation process is considered to be over when the return stroke reaches the cloud base.

The earth is treated for simplicity as a perfectly conducting plane with its electrical effect replaced by an image current. Since image charges have reversed signs and velocities, the image current will have the same intensity and direction at a point a given distance below the earth's surface that it has at the corresponding point above the surface at the same instant.

Our assumptions concerning the current in the channel can be summarized as follows. Let X be any point on the channel at a distance x below the cloud base, as is indicated in Fig. 2. The current at X, measured positively in the upward direction, is composed of the following contributions.

$$(a) \qquad 0 \leqslant t < x/v_l, \qquad I = 0, \tag{8}$$

$$(b) \qquad x/v_l \leqslant t \leqslant h/v_l, \qquad I = 6\pi a \epsilon_v E v_l^2 t, \tag{9}$$

$$(c) \qquad \frac{h}{v_l} \leqslant t < \frac{h}{v_l} + \frac{h-x}{v_r}, \qquad I = 6\pi a \epsilon_v E v_l h, \tag{10}$$

$$(d) \quad \frac{h}{v_l} + \frac{h-x}{v_r} \leqslant t \leqslant \frac{h}{v_l} + \frac{h}{v_r},$$

$$I = 6\pi a \epsilon_v E v_r^2 \left(\frac{h}{v_l} + \frac{h}{v_r} - t \right) + I_f. \tag{11}$$

After the instant $t = h/v_l + h/v_r$ the residual current I_f continues to flow but, as stated already, we consider the radiation process to be complete. In these expressions v_l is the speed of the leader stroke and v_r that of the return stroke, for which empirical values will be used in the later analysis.

3. THE CALCULATION OF THE RADIATION FIELD

Let P in Fig. 2 be the distant point at which one wishes to find the radiated field. If $\mathbf{k}$ is a unit vector measured vertically upward from the surface of the earth, the vector potential at P is (MKS units)

$$\mathbf{A}(P,t) = \mathbf{k} A(P,t), \tag{12}$$

with

$$A(P,t) = \frac{\mu_v}{4\pi} \left[\int_0^h \frac{I(x, t - \zeta/c)}{\zeta} \, dx + \int_0^h \frac{I(x, t - \zeta'/c)}{\zeta'} \, dx \right]. \tag{13}$$

Here

$$\begin{aligned} \zeta &= (r^2 + y^2 - 2ry\cos\theta)^{\frac{1}{2}}, \\ \zeta' &= (r^2 + y^2 + 2ry\cos\theta)^{\frac{1}{2}}. \end{aligned} \tag{14}$$

The first member in Eq. 13 gives the field from the real channel while

the second member gives that from the associated earth currents as represented by the image channel.

The magnetic induction vector can be found from the usual formula, $\mathbf{B} = \text{curl } \mathbf{A}$. Making use of the unit vector system for spherical polar coordinates with origin at the point O in Fig. 2, it is found that

$$\mathbf{B}(P,t) = -\,\phi_1\left[\sin\theta\left(\frac{\partial}{\partial r}+\frac{2}{r}\right)\right]A(P,t). \tag{15}$$

Only the leading term which diminishes as $1/r$ is required for the calculation of the radiation field. The function $A(P,t)$ has a leading term which diminishes as $1/r$ and only terms of this type need be retained in the calculation of Eq. 15. To this approximation we find

$$A(P,t) = \frac{\mu_v}{4\pi r}\left\{\int_0^h\left[I\left(y,t-\frac{r}{c}+y\frac{\cos\theta}{c}\right)+I\left(y,t-\frac{r}{c}-y\frac{\cos\theta}{c}\right)\right]dy\right\}. \tag{16}$$

It is convenient to introduce a Fourier integral representation for the channel current in the form

$$\frac{\mu_v}{4\pi}I(y,t) = \int_0^\infty\left[\varphi(y,\omega)\cos\omega t+\psi(y,\omega)\sin\omega t\right]d\omega, \tag{17}$$

with

$$\left\{\begin{matrix}\varphi(y,\omega)\\ \psi(y,\omega)\end{matrix}\right\} = \frac{\mu_v}{4\pi^2}\int_{-\infty}^{+\infty}I(y,t)\left\{\begin{matrix}\cos\omega t\\ \sin\omega t\end{matrix}\right\}dt. \tag{18}$$

On insertion of these quantities into Eqs. 15 and 16 one finds the following expression for the magnetic induction vector of the radiation field:

$$\mathbf{B}(P,t) = \phi_1\frac{\sin\theta}{r}\left\{\int_0^\infty\frac{\omega}{c}\left[-M(\omega,\theta)\sin\omega\left(t-\frac{r}{c}\right)+N(\omega,\theta)\cos\omega\left(t-\frac{r}{c}\right)\right]d\omega\right\}, \tag{19}$$

with the definitions

$$\left\{\begin{matrix}M(\omega,\theta)\\ N(\omega,\theta)\end{matrix}\right\} = 2\int_0^h\left\{\begin{matrix}\varphi(y,\omega)\\ \psi(y,\omega)\end{matrix}\right\}\cos\left(\frac{\omega y\cos\theta}{c}\right)dy. \tag{20}$$

The radiative part of the electrical field can be found from the general formula

$$\mathbf{E}(P,t) = -\,c\mathbf{r}_1\times\mathbf{B}(P,t), \tag{21}$$

where $\mathbf{r}_1$ is the unit radial vector drawn from O to P in Fig. 2.

The radiation intensity is given by the Poynting vector

$$\mathbf{S} = \frac{1}{\mu_v}\mathbf{E} \times \mathbf{B} = \frac{c}{\mu_v}|\mathbf{B}(P,t)|^2 \mathbf{r}_1. \tag{22}$$

The spectral distribution of the radiation can be found by integration of the Poynting vector formally over the range $-\infty < t < \infty$, with use of the Fourier resolution given in Eq. 19. Since the current in the stroke exists only over a bounded time interval and is always finite in magnitude, the spectral resolution will satisfy Parseval's theorem, so that

$$\int_{-\infty}^{+\infty} |\mathbf{S}|\,dt = \int_0^\infty W(r,\theta,\omega)\,d\omega, \tag{23}$$

with the spectral function

$$W(r,\theta,\omega) = \frac{\sin^2\theta}{r^2}\cdot\frac{\pi\omega^2}{\mu_v c}[|M(\omega,\theta)|^2 + |N(\omega,\theta)|^2]. \tag{24}$$

This function gives the total amount of radiation which flows past the distant point P, measured in units of joules per meter^2 per unit (angular) frequency interval. The total radiated energy passing P, in joules/meter^2, is obtained by integration of $W(r,\theta,\omega)$ with respect to ω over the range $0 \leqslant \omega < \infty$.

4. THE SPECTRAL FUNCTION

The calculation of the spectral function, as defined in Eq. 24, is straightforward after the discussion of Secs. 2 and 3. The integrals which result from the substitution of expressions 8–11 into formulas 18 and 20 are all elementary although somewhat cumbersome. The full result is given for the sake of the reader who may wish to check it, but the notation is abbreviated for typographical simplicity. We use the following nomenclature:

$$\beta = 3\alpha E/2\pi c^2, \qquad \gamma = \omega h/2v_r, \qquad \eta = v_l/v_r,$$

$$a_\pm = \frac{\omega h}{v_r}\left(1 \pm \frac{v_r\cos\theta}{c}\right), \qquad b_\pm = \frac{\omega h}{v_l}\left(1 \pm \frac{v_l\cos\theta}{c}\right). \tag{25}$$

Our formula is

$$e^{-i2\gamma/\eta}[M(\omega,\theta) + iN(\omega,\theta)] = \frac{2\beta}{\omega^2}\left\{[(v_l^2 - v_r^2 e^{i2\gamma})h]\frac{\sin\left(\frac{\omega h\cos\theta}{c}\right)}{\left(\frac{\omega h\cos\theta}{c}\right)} + \right.$$

$$+\frac{\omega h}{v_l}\frac{iv_l^2h+\omega v_lh^2}{b_+b_-}+\frac{\omega h}{v_r}\frac{iv_r^2h+\omega(v_l-v_r)h^2}{a_+a_-}$$

$$-\frac{iv_l^2h}{2}\left[\frac{e^{-ib_+}}{b_+}+\frac{e^{-ib_-}}{b_-}\right]-\left(\frac{iv_r^2h+\omega v_lh^2}{2}\right)\left[\frac{e^{ia_+}}{a_+}+\frac{e^{ia_-}}{a_-}\right]$$

$$-\frac{i\omega v_lh^2}{2}\left[\frac{e^{-ib_+}-1}{b_+^2}+\frac{e^{-ib_-}-1}{b_-^2}\right]$$

$$-\frac{i\omega v_rh^2}{2}\left[\frac{e^{ia_+}-1}{a_+^2}+\frac{e^{ia_-}-1}{a_-^2}\right]\Bigg\}. \quad (26)$$

When one proceeds to the calculation of the spectral function from Eq. 24 by use of 26, the resulting expressions become very cumbersome. Fortunately many of the terms can be seen to be of small numerical significance. The apparent strong dependence on the angle θ arises from Doppler effects and is not important since we know that $v_l \ll v_r \ll c$. It is sufficiently accurate for present purposes to treat the angular distribution of the radiation as that of a dipole with its axis along the channel. All effects of the residual current have been ignored in Eq. 26 as giving a negligible contribution to the radiation.

It has been judged unprofitable to make a complete numerical analysis of the radiation with use of Eq. 26 at the present time. An analytical approximation of sufficient accuracy to show the most important features of the calculation has been developed on the basis of the radiation from the return stroke alone. If we write

$$|M+iN|^2=\beta^2h^4\gamma^{-2}F(\gamma), \quad (27)$$

the following expression has been found for $F(\gamma)$:

$$F(\gamma)=|j_1(\gamma)|^2=\gamma^{-4}(\sin\gamma-\gamma\cos\gamma)^2, \quad (28)$$

where j_1 is the spherical Bessel function of first kind of order unity.

This formula can be used to complete the evaluation of the total electromagnetic energy emitted in the stroke. One has only to integrate the Poynting vector over the hemisphere into which the radiation flows. If R is the radiated energy in joules per unit (angular) frequency interval, one finds that

$$R=\frac{16\pi^2\beta^2v_r^2h^4}{3\mu_0c}F(\gamma). \quad (29)$$

It is useful to introduce the total charge on the channel at the instant contact is made with the ground as a parameter. Equation 5 shows that this charge is

$$Q(h)=-3\pi a\epsilon_0Eh^2. \quad (30)$$

When this quantity is introduced into formula 29 and the units of the frequency scale are changed to cycles/sec, one finds the expression

$$R = \frac{8}{3\pi c\epsilon_v} |Q(h)|^2 (v_r/c)^2 F(\gamma) \frac{\text{joules}}{\text{cycle/sec}}. \tag{31}$$

This result shows that to the approximation considered the total radiation and its spectral distribution depend on three simple characteristics of the stroke: (*a*) the total charge deposited on the channel during the leader stroke, (*b*) the speed of the return stroke, and (*c*) the time of travel of the return stroke. The form of the spectral distribution is determined by the last quantity alone since it fixes the function $F(\gamma)$.

5. THE CHOICE OF NUMERICAL DATA

The orders of magnitude of the major physical constants associated with a lightning stroke are known, but it is not easy to establish a self-consistent and definitive set of values. Fortunately our model makes minimum requirements on this choice.

Pierce (**8**) estimates from his work that during the development of the leader stroke a total negative charge of about 5 coulombs is lowered to earth from the cloud. If we interpret this as the charge which is deposited on the channel during the leader stroke, and which is removed to earth by the return stroke, we find that

$$|Q(h)| = 5 \text{ coulombs}. \tag{32}$$

This result allows us to make a check on our model by the estimation of the value of the empirical parameter α. On making use of formula 30 and the numerical value given in 32 one finds that $\alpha = 2/3$. This is in very satisfactory agreement with the argument of Sec. 2, according to which the value of α was expected to be a little smaller than unity.

The position of the maximum of the spectral distribution can be found from the definition of the parameter γ given in Eq. 25 and the formula 28 for $F(\gamma)$. The maximum is found to occur at $\gamma_m \cong 2.1$, from which the corresponding frequency is

$$f_m = (v_r/\pi h)\gamma_m = 0.67/T_r. \tag{33}$$

Since the experimentally observed value of f_m is in the neighborhood of 10–12 kc/sec, we adopt the value

$$T_r = 60 \ \mu\text{sec}. \tag{34}$$

The speed of the return stroke is known to be of the order of 10 per cent of the speed of light. Schonland (**6**) gives a figure of 60 μsec for the time of travel up a channel of height $h = 2$ km and also the

somewhat smaller value of 2×10^7 m/sec for the mean speed of the return stroke. It seems reasonable to adopt the round number

$$v_r = 3 \times 10^7 \text{ m/sec.} \tag{35}$$

There is some uncertainty at present in the estimation of the mean speed of the leader stroke. According to the work of Pierce and Wormell (9) it is appreciably lower than the figure given by Schonland and others. A recent review by Pierce (8) gives the value $v_l \cong 6 \times 10^4$ m/sec. This is not a critical point here since our approximate formula 31 for the total radiation does not involve this constant at all, and it is quoted only for purposes of comparison.

6. THE SPECTRAL DISTRIBUTION OF THE RADIATED ENERGY

When the numerical values adopted in Sec. 5 are inserted into formula 31 the following explicit expression results:

$$R = 8 \times 10^4 \, F(\gamma) \, \frac{\text{joules}}{\text{kc/sec}}. \tag{36}$$

A plot of the function $F(\gamma)$ is shown in Fig. 3. Using the numerical

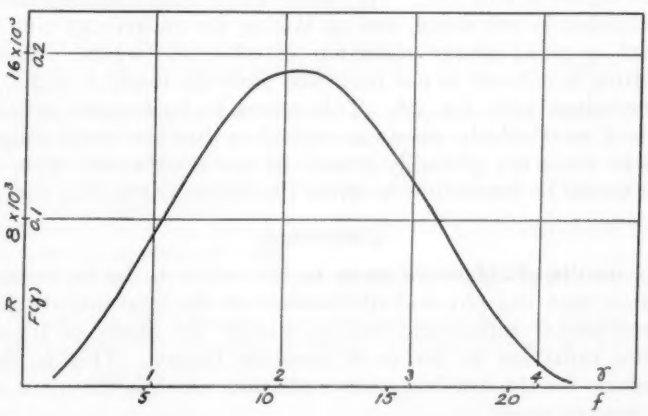

FIG. 3. Plot of the function $F(\gamma) = \gamma^{-4} (\sin \gamma - \gamma \cos \gamma)^2$ giving the spectral distribution of the emitted radiation. The scales for the frequency, f, in kc/sec, and for the emitted radiation, R, in joules/(kc/sec), are fixed by the choice of constants discussed in the text.

values given one finds that the frequency at the maximum point is $f_m = 11.2$ kc/sec, while the total width at half-maximum is about 12 kc/sec. Integration over the spectral distribution yields a total energy emission of about 220,000 joules.

The behavior of our formula at the extreme ends of the spectrum

is of interest. At the low-frequency end we find that

$$f_{kc} \ll 10^{-3}/\pi T_r, \qquad R \cong 32\pi^2 (f_{kc})^2 \frac{\text{joules}}{\text{kc/sec}}. \tag{37}$$

No detailed experimental data are known to the writer for comparison with this formula. Estimates have been made on the basis of waveform analyses (2, 4) which appear to yield a smaller decline in the radiated energy with decreasing frequency. The writer is inclined to favor the theoretical results given here, but the decision must await better experimental results.

At the high frequency end of the spectrum one finds from Eqs. 28 and 36

$$f_{Mc} \gg 10^{-6}/\pi T_r, \qquad R \cong 1250/(f_{Mc})^2 \frac{\text{joules}}{\text{Mc/sec}}. \tag{38}$$

Here a factor $\cos^2 \gamma$ has been replaced by its mean value 1/2. A rough comparison of this formula with the results reported recently by Chandrashekhar Aiya is possible (3). Aiya's work is statistical in nature and refers to measurements with a noise meter having an effective bandwidth of 6 kc. He counts a lightning discharge as having 3 unit strokes in our sense, and as lasting for an average time of 0.2 sec, with a mean power radiation of $45/(f_{Mc})^2$ watts. When this information is reduced to our units one finds the result $R = 500/(f_{Mc})^2$ for comparison with Eq. 38. This seems to be a quite satisfactory agreement, particularly when one considers that the tropical lightning strokes in India are probably mostly of the cloud-cloud type. However, it would be premature to stress the agreement at this time.

7. DISCUSSION

The results of this work seem to the writer to be an encouraging indication that the physical mechanism of the lightning discharge is now understood sufficiently well to justify the study of its electromagnetic radiation in terms of absolute theory. This is the case particularly for the low frequency radiation which is the main concern in the present paper.

One point which remains somewhat unclear concerns the extent to which the position of the maximum in the spectral distribution curve varies in frequency from stroke to stroke. This is suggested by the fact that the height of the cloud bank as observed visually varies widely from storm to storm, indicating that the length of the discharge channel may be quite variable.[3] Nevertheless, it seems to be believed generally that the maximum radiated intensity lies fairly closely around

[3] This point has been emphasized to the writer by Mr. S. Hersperger of the University of Florida.

12 kc/sec, although no definitive measurements are known to the writer. Such a result may be explained by the consideration that often an unobserved part of the discharge channel may lie inside the cloud, so that the visual position of the cloud bank would not be a direct measure of the channel length. Furthermore, from the point of view of the model considered in this paper, the quantity which determines the spectral distribution of the radiation is the time of travel of the return stroke. Since the longer discharge channels can be expected to be associated with larger amounts of charge deposited on the channel by the leader stroke, it may be that the mean speed of the return stroke is then also increased. Thus there may arise a correlation between channel length and stroke speed such that their ratio is more nearly constant for all types of discharge than is either of these quantities separately.

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"Deep Freeze" Metallurgy.—Ford Motor Company scientists are trying to unlock some of the mysteries of metals by studying them at temperatures near the absolute zero mark of minus 459° F. While the art of alloying is thousands of years old, little is known of why metals behave the way they do, according to Andrew A. Kucher, director of Ford's Scientific Laboratory in Dearborn, Mich.

"It is only when they are placed in the deep freeze of several hundred degrees below ordinary temperatures that the motion of the atoms slows down enough for us to uncover the secrets of metal behavior," he said.

Studies at Ford's Scientific Laboratory show that metals often do strange things at ultra low temperatures. Some metals which show no magnetic behavior at room temperature become forceful magnets. Some least expected materials, such as diamonds and quartz, become excellent heat conductors. Lead, aluminum and many other metals change into superconductors of electricity. An electrical current started in a loop of lead wire would last forever if the metal were kept at these low temperatures.

Ford scientists use liquid helium to obtain their low temperatures. Helium, normally a gas, turns to a liquid at − 452° F. Substances immersed in it are lowered to this temperature through contact.

Dr. Kucher is hopeful that the Scientific Laboratory in time will be able to achieve temperatures of less than 1/10th of a degree of absolute zero, approaching the coldest temperatures ever obtained by man.

"We feel our studies may lead to the development of new tailor-made alloys that will be able to serve new useful purposes on the expanded horizons of the future," Dr. Kucher explained.

Face Shield Against Arctic Cold.—A new type Face Shield for use by troops or others required to work in extremely cold climates has been developed and patented by Kenneth L. Treiber of the Corps of Engineers' Research and Development Laboratories, Fort Belvoir, Virginia. The patent, presented by Maj. Gen. David H. Tulley, Commanding General, is Treiber's fourth at Belvoir. Previously, he had received patents for a pressure-indicating closure seal for collapsible liquid containers, for a 10,000 gallon collapsible storage tank, and for a dispensing device for installation of flexible hoseline from aircraft or from a moving vehicle.

The Face Shield is designed particularly for use under severe conditions of climatic cold and precipitation such as encountered in Arctic regions where personnel are required to perform outside duties notwithstanding severe cold and other adverse weather conditions.

Mr. Treiber first thought of the idea of a face shield for use in cold climates as the result of a painful experience he, himself, had in the Arctic in 1947. While at Fort Churchill, he suffered a frozen cheek and "this made me think how stupid it was to have the rest of the body well-protected from the cold and, yet, leave one's face virtually unprotected."

His new Face Shield remains free from cloudiness resulting from condensed moisture of respiration, and incorporates an improved, readily adjustable mounting which permits upward rotation through an arc of 90 degrees for a short period of time. Its head harness is adjustable as to size. The main shield and inner frost apron are of transparent plastic material such as synthetic vinyl plastic, also known as "Plexiglass."

FROM IMBIBITION TO EXHIBITION *

A Reconstruction of a New Photographic Process

BY

EDWIN H. LAND [1]

To let you settle down a bit I will start with the Exhibition part of this lecture and show pictures of the Institute and of Philadelphia taken by one of our specialists from Boston in the last day or two; some of them, indeed, this afternoon, to prepare the way for our advent here. I warn you now, however, that after these pictures the Imbibition part of the lecture will begin. And, quite suddenly, if you will listen very carefully, I will be giving you a concentrated talk on all there is to know about this process.

(The lecture hall was then darkened and Dr. Land projected on the screen a number of black and white transparencies, beginning with a view of an open and alert human eye, filling the full screen, and proceeding through views of the Institute, its officers, and a number of other scenes taken in the city.)

I should mention that all of the slides we will see tonight were made by the process we are talking about. They were photographed on a film which forms a transparency slide directly in the camera. I should also mention that all of these pictures, including the night views, were taken without flash bulbs and at moderate exposures. The film with which these transparencies are made has a speed of ASA 1000; it is, therefore, possible to take most pictures with the light as it exists, and so reproduce the scene as it appears to the eye, rather than permit its appearance to be altered by accidental lighting that one gets with flash bulbs.

Considering the problem of how, possibly, you could develop a picture directly in a camera with no liquids in it, the first thing that might come to you, in fantasy, is that it would be nice if you could do it in one, apparently-dry, step. My own earliest fantasy took this form, a fact that may be of value to those who are interested in the inventive process. In the beginning, I thought in terms of a camera having within it a pair of small steel rollers which might somehow quickly convert the exposed film into the finished picture.

This presented something of a problem, because there is no obvious way at all in which such a pair of rollers can accomplish the task.

* A lecture-demonstration of one-step photography, presented at the 1956 Medal Day Meeting of The Franklin Institute, October 17, 1956.

[1] 1956 Potts Medalist; President and Director of Research, Polaroid Corporation, Cambridge, Mass.

The next mental step was, then, to say that if a film could exist which wasn't really dry, but which would *appear* to be dry, and that if this film could somehow be made to develop itself; then, for the person using the camera it would be just as good as the fantastic one which develops itself merely by passing through the rollers without anything happening whatever. So, the mental exploration began.

Could processes coexist which would form a picture in one single step? The temptation was to consider processes used in blue-print machines. These processes produce a positive image directly, without recourse to a negative image. Thus we might eliminate the tediousness of considering how to get from negative to positive in one step. But the low efficiency of these processes brings us up short. In processes of the blue-print type there is a direct correspondence between the units of light absorbed by the film and the units of image-creating material formed in the film.

Photography as we know it today and as we have known it for the past seventy-five years is enormously more efficient than that. Its efficiency is remarkable in several ways. Perhaps the most remarkable thing about it is its demonstration of the capacity of the human being to use deep, internal, intuitive resources in solving problems, in domains of great importance, generations before science has come to exist in these domains. In medicine we see this happening continuously; most medical problems are solved fifty or one hundred years before anyone understands *how* they are solved.

In photography a technique was worked out generations ago, without benefit of science, for obtaining an amazing multiplication of the effect of the light that falls on the photo-sensitive material. Now, generations later, we understand it a little better; many of you of course know all about it. But it was by intuition that the human race first arrived at the technique. What happens is that each of the silver halide grains lying in the gelatin medium of the photo-sensitive material collects all of the light falling upon its entire surface and concentrates it into one minute area to form a microscopic speck of silver, much smaller than the grain itself. This speck becomes the catalyst which later causes the developer to operate upon the whole large area and to convert it into a black, absorbing, image-forming element. The multiplication occurs twice.

Compared to this achievement, nothing that we could invent seemed worth considering except through sheer stubborness. In exploring the one-step process, there seemed to be enough opportunities to be stubborn without trying to substitute something new for this wonderful silver-halide emulsion. So, at this early stage, we determined to use the old-fashioned, wonderful negative materials, adapting them to our special needs.

With this consideration out of the way let us proceed with the

exploration of some of the remaining problems. We first recall how the positive image is achieved in ordinary photography. We start with a light-sensitive silver-halide emulsion. When the original exposure is made, light falls on the silver bromide grains. If there is enough light, a speck of silver is produced at one edge of the silver bromide grain. If there is not enough light, no speck of silver is produced. Then, in ordinary processing, a developing agent is applied to the emulsion. The developer delivers electrons to the exposed grains. Silver ions migrate through the grains and deposit themselves on the minute speck that has resulted from the original exposure. The whole grain is promptly converted to black silver. In the unexposed grain this does not occur; presumably there is no way in which the developer can deliver electrons to it. Then, in ordinary processing, the unexposed grains are dissolved with hypo, a good solvent for silver bromide. The hypo is washed out with water. The sheet is then dried and we have a finished negative image. The process is then repeated. The original negative image is placed in contact with another light-sensitive sheet called the positive. It is again exposed to light, developed, fixed, washed, and dried. And we have a finished positive.

You know the photographic dark room, where all these steps are carried out, as a fine, romantic place—a place of silver and hypo and darkness. Our problem is to carry out all of these operations in one step in a dry camera, without any tanks or baths—and without a dark room. Every technological revolution carries in its wake disastrous consequences for some sentiment.

In our approach to this problem, let us walk before we run, and start with an extraordinarily simple experiment. On an exposed photographic plate, place one drop of developer, and over the plate press down a cover glass. You will see that this one drop of developer—1/600 ounce—develops an area about two inches in diameter. From this experiment came one of our most exciting early concepts—the idea of using just a few fresh drops of developer for each picture.

When you try to do that, however, you find that developers are difficult to spread uniformly as liquids. This immediately gives rise to the thought: Why not make a viscous developer, one that will be thick enough to spread easily?

With the assistance of my colleague Miss Morse, let us try another experiment. Here we have a liquid developer, quite strong and concentrated. As Miss Morse pours it back and forth, you will notice that it gradually darkens. It is a reducing agent and it oxidizes rapidly in air. This calls attention to another consideration: it would be advantageous if, in the process we are reconstructing, we could confine the developer, protect it from the air, and so preserve it until we are ready to use it.

This indeed is actually what we do in our process. We use a viscous,

jellied reagent and we confine it in a pod, a little envelope lined with metal foil and plastic, sealed permanently along three edges, and with the fourth edge sealed in such a way that it will stay firmly sealed until it is ready for use, but will open if enough pressure is applied. One of these pods filled with jellied reagent is provided for each picture. In Fig. 1 you will see the arrangement of the steel rollers with which we

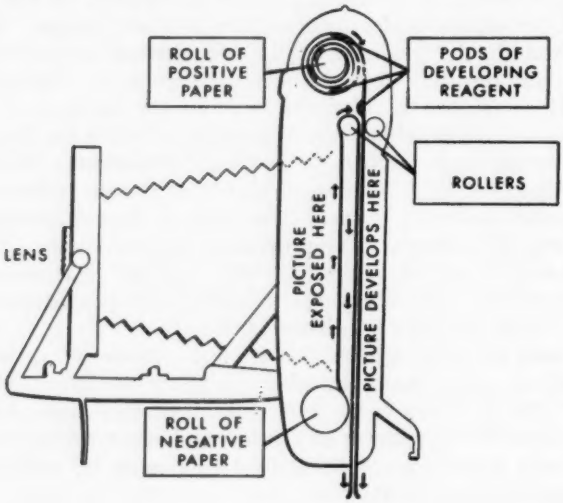

FIG. 1.

started, and the spooled roll of silver halide negative material. You can easily foresee that when this pod is subjected to the bite of the narrow-spaced rolls, the hydraulic pressure within the pod will instantly cause the reagent to burst through the lightly sealed trailing edge, and the jellied reagent will be distributed as a thin layer between the negative sheet and sheet of paper on which the positive is ultimately to be formed. Observe that the jellied reagent is confined first in the pod; then between positive and negative.

Now let us actually use one of these pods in developing a negative image.

So that you can see what happens, we are using an extremely slow negative material and an orange light to which it is not sensitive. On this material we have exposed an image, ready for development. At one edge we attach a pod of reagent, and over it we place a transparent plastic sheet; transparent so that you can see through it to the negative sheet. We pass the two sheets, with the pod between them, through this pair of steel rollers. Instantly, as you see, the development process begins. The metallic silver is being reduced to form a visible image;

first, in the portions of the negative which has received the most light; now, a few seconds later, the middle tones.

We have seen how a viscous developer, contained within a pod, can be used to develop a negative.

In our reconstruction, we have arrived at the question: How can we, at the same time, make a positive? In Fig. 2 we see an extremely simplified section of the sandwich as it lies in the camera after it has been drawn through the rolls. At the top we have the negative sheet, with its light-sensitive emulsion; one grain of silver halide exposed, the other not exposed. Then, as the center of the sandwich, we have the layer of reagent; we have used the symbol *D* to represent the developer-component of the reagent. The symbol *H* stands for a solvent for silver halide; we have used quotation marks to indicate that this solvent is not always hypo. The lowest layer in the diagram represents the sheet which is to receive the positive image. The little black rectangles which you see on this sheet represent catalytic nucleating particles that we have planted there in a coating on this sheet. We will return to these in a moment.

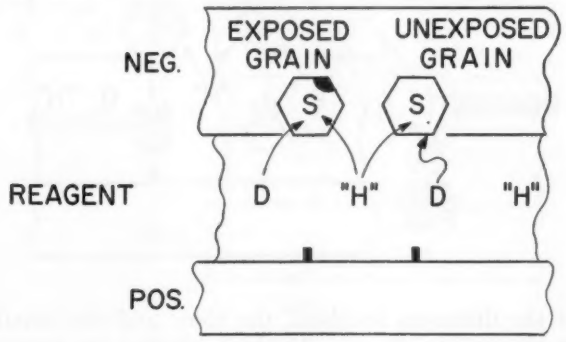

FIG. 2.

When the reagent is spread in the sandwich, the liquid components of the reagent are imbibed into the silver halide emulsion. In this situation, Fig. 3, a competition exists between the developer and the solvent. The developer proceeds to convert the exposed silver halide grain into metallic silver; the solvent tries to dissolve all the silver halide that it can find. It cannot dissolve the exposed grain because it doesn't dissolve silver at all rapidly; we see that the hypo has visited the exposed grain, has found it already converted into insoluble metallic silver, and is coming away empty-handed, but it does dissolve the unexposed grain and it is carrying off its load of solubilized silver.

We are ready, now, for the creation of the positive image. It is required that the solvent hold onto its load of silver ions well enough so that these ions are not developed by the surrounding developer until

we are ready to have them developed. If the loads of silver ions carried by the solvent were readily developed and precipitated by the developer, all would be lost.

It is here that the catalyst comes into play, Fig. 4; the catalyst indicated by the little black rectangles contained in a coating we have placed on the positive sheet. It is this catalyst that causes the developer to reduce and precipitate the silver ions that have been carried over from the negative sheet by the solvent.

You can now visualize the process: It is a one-step activity in which we are pulling away the unexposed grains and turning them to silver on the surface of the positive sheet.

There has been some confusion in people's minds about our process; they think of diffusion as being a slow, time-consuming, spreading operation. They think that the silver will wander during the trip from negative to positive, and they are surprised that it does not. But let

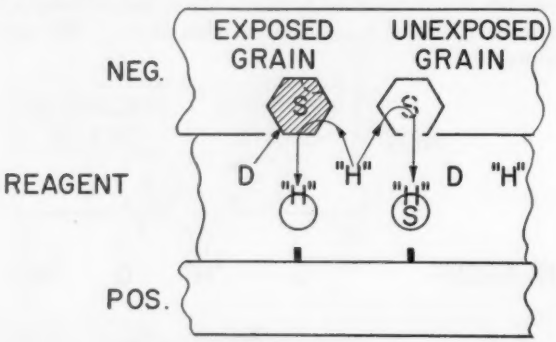

FIG. 3.

us consider the distances involved, the time, and the function of the catalyst on the positive layer. At the beginning the reagent layer is about 0.003 in. thick. The liquid components of the reagent, however, are immediately imbibed in the emulsion, leaving the thickener as the chief component between the emulsion and the paper that is to receive the positive image. The thickness of this layer is consequently extremely small during the latter part of the process—on the order of 0.0001 in. The solvent has, indeed, a very short trip to make with its load of silver ions.

The catalytic coating on the positive sheet is so important because it causes precipitation to occur rapidly; the ions are converted to metallic silver the instant they touch the positive sheet. No time is lost. It is on this instant precipitation of the silver that the brilliance, the sharpness and the success of the images depend.

Let us look at an experiment which will show the power of the catalytic coating of the positive sheet. Again we will run a sandwich

through our laboratory rolls. In this case the negative has not been exposed at all; and it remains unexposed, here in the light, because it is so slow. You will observe that the positive sheet appears to be a piece of plain white paper. Actually, however, the words "Franklin Institute" have been written upon it with the catalytic material. Now, with the pod of reagent between them, we pass the two sheets through the rolls. We wait for a minute for the process to complete itself; then strip the sandwich apart. We now see the power of the catalyst: Where the catalyst was not present nothing has happened; the paper is as white as before. Where the catalyst was placed on the positive sheet, there is a black image spelling out the words. Recall that the solvent, carrying a uniform load of silver ions from the unexposed negative, was uniformly distributed over the whole sheet. Where the catalyst was present, the loads of silver ions were unloaded as a positive image. Where the catalyst was not present, the solvent could not discharge its load.

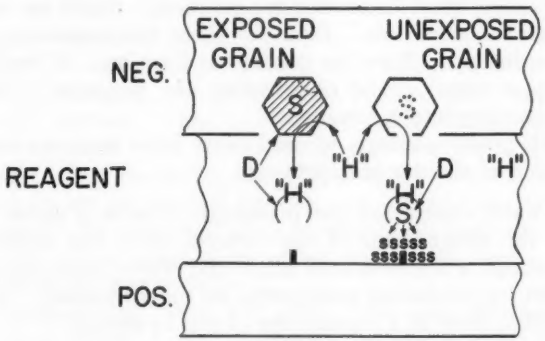

FIG. 4.

A great deal of our work during the last ten years has had to do with this question of the loading of the solvent with silver ions at the negative sheet, and the disembarkation of the silver on the surface of the positive sheet.

In Germany, they have worked for years on the transferring of silver positives and this work is the basis for many of the document-copying machines that are in use today. In this document-copying field the emulsions are of fine grain, usually silver chloride, very soluble and of course very slow. Because of the fine grain, the use of silver chloride rather than silver bromide, and the high solubility of the chloride, the amount of solvent needed is small. When one attempts to use fast negative materials of the type with which we make photographs as we ordinarily know them, one encounters the relatively large silver bromide grain. This bromide grain is relatively insoluble as

compared with silver chloride, and when one attempts to accomplish the transfer by using large amounts of solvent these large amounts of solvent move into the negative, tend to combine and form complexes with it and even tend to stay there. You cannot, in general, use enough solvent to take all of the silver halide out at one trip; in effect, the solvent ferryboats get jammed at the port of embarkation, all traffic comes to a standstill. For this reason a major part of our activity has been the development of the art of using small amounts of solvent, with efficient receiving quays at the other end of the trip, that will permit instant unloading. If you unload rapidly enough, then you can use a small amount of solvent and use it over and over again to carry repeated loads of silver ions.

We should now like to show you a negative and a positive actually forming together, as they form in one of our cameras.

So that you can see the demonstration we will use an emulsion that is not sensitive to yellow light. It carries a latent image. We will use a transparent sheet to receive the positive. Again we pass a sandwich through the steel rolls. First, for these few moments, you see the negative coming up. Now the positive is forming. It begins to overtake and now seems to be obliterating the negative. The positive image is soon completely dominant.

With this positive image, formed as we have seen, we complete our reconstruction of the one-step process.

(Dr. Land concluded the presentation with a series of slides showing the progression of the process from the original sepia prints through a succession of black-and-white films and the most recent film for producing transparencies for projection. The series ended with a view of a human eye closed in sleep.)

THE MAGNETO-IONIC EXPANDER ISOTOPE SEPARATOR

BY

JOSEPH SLEPIAN [1]

ABSTRACT

The Magneto-Ionic Expander is the outcome of thirteen years of failure with the Ionic Centrifuge. Failure of the Ionic Centrifuge is described and the operation of the Magneto-Ionic Expander is explained. The Magneto-Ionic Expander offers pure isotopes of metals more cheaply than any other method known to the author.

The Magneto-Ionic Expander is new to physicists. The first publication[2] is less than a year old;[3] the second, a Letter to the Editor, appeared in October, 1955.[4]

I. THE MAGNETO-IONIC EXPANDER AROSE FROM IONIC CENTRIFUGE

The Magneto-Ionic Expander was developed after thirteen years of failure with the Ionic Centrifuge, a form similar in theory at least to the mass spectrometer or to the Calutron.

The Ionic Centrifuge began with a short arc about a quarter of an inch in length, between two electrodes, in a parallel magnetic field, and in a high vacuum. The anode was the metal whose separated isotopes were desired. At the time, it was uranium. The cathode was a cored carbon made by the National Carbon Company. We usually used an arc current of 10 amp., giving an ion current to the vacuum space of about one half of an ampere. We have run a 100-amp. arc, yielding to the vacuum space about 10 amp. of ions. We do not know how much further we may go.

The arc voltage was 20 to 100 volts. The neutral yield was very small, less than 10 per cent of the anode ion yield. The cathode was hardly consumed. The vacuum was easily held at 10^{-5} mm.

The manner in which we expected the Ionic Centrifuge to work was quite simple, though quite erroneous. If there is a very small current of positive ions at the origin, they will reach a radius r, perpendicular to the magnetic field, only when the potential, which originates at the origin, has the value at r equal to

$$V_L(r) = -\frac{e}{c^2 8m} H^2 r^2. \qquad (1)$$

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[1] Westinghouse Research Laboratories, East Pittsburgh, Pa.

[2] Joseph Slepian, "Isotope Separation by Ionic Expansion in a Magnetic Field," *Proc. Nat. Acad. Sci.*, Vol. 41, pp. 451–457 (1955).

[3] ED. NOTE: The manuscript of Dr. Slepian's present paper reached the JOURNAL office in May, 1956.

[4] Joseph Slepian, "Failure of the Ionic Centrifuge Prior to the Ionic Expander," *J. Appl. Phys.*, Vol. 26, p. 1283 (1955).

Hence, if the potential were to be adjusted so that it would be between the two isotopic values at the radius r, the heavier isotope would be caught on a cylindrical collector at r, and the lighter isotope would be caught on the end plates terminating the vacuum space, above and below the arc (Figs. 1 and 2).

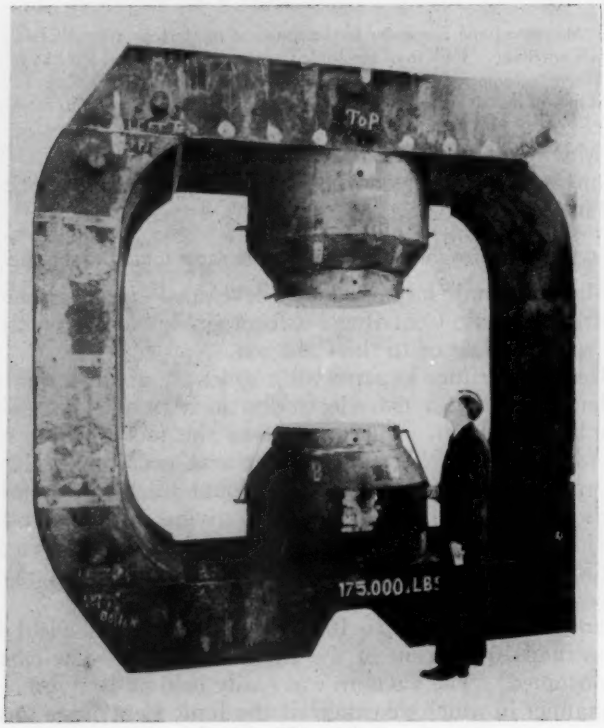

FIG. 1. Magnet frame.

We thought the current would be very small since, with no electrons present, the space charge would keep the positive current small. That would easily be taken care of by raising the potential of the end plates to a high enough negative value to generate the small number of electrons needed for space charge neutralization.[5]

To our great surprise and disappointment, however, when we built the apparatus shown in Figs. 1 and 2, and confirmed the large ion yields

[5] L. P. Smith, W. E. Parkins and A. T. Forrester, "On the Separation of Isotopes in Quantity by Electromagnetic Means," *Phys. Rev.*, Vol. 72, pp. 989–1002 (1947).

These men had already found but not yet recognized the results of electrons set free, and travelling with the positive ions, and going out opposing the impressed electric field. Dr. Wilson M. Brubaker and I had also discovered the phenomenon, but continued for thirteen years before learning how to use it.

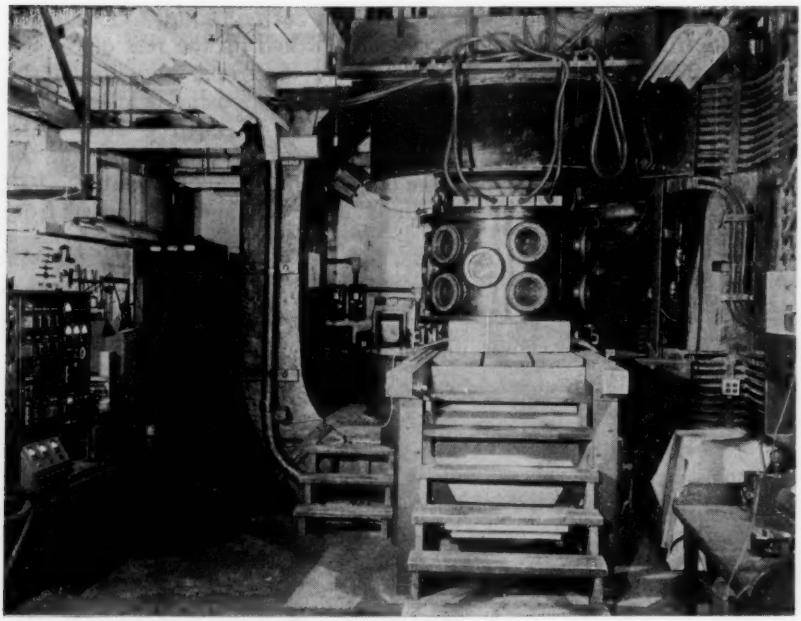

FIG. 2. Operating assembly.

obtained from the arc, we obtained both ions and electrons depositing out upon the bounding cylinder. If the cylinder was kept insulated, its floating voltage did not stay at zero because of lack of electrons, but it rose to the Larmor voltage of Eq. 1 (Fig. 3). At the same time,

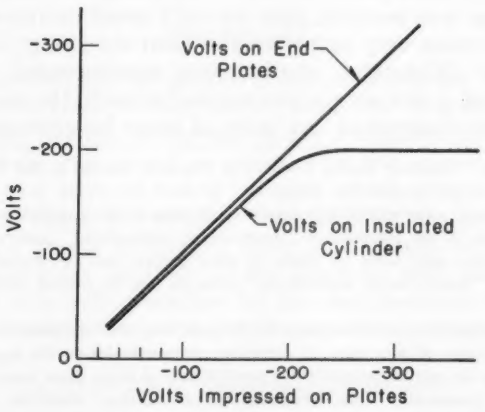

FIG. 3.

while the end plates showed a positive ion current equal to about one half the arc yield, the insulated cylinder picked up the rest of the ion current plus an equal charge of negative electrons. We found the large number of electrons moving against the opposing field when the Larmor voltage was − 30 volts and when it exceeded − 2000 volts. To make matters worse, the impoverishment of the deposit on the insulated cylinder over that on the end plates remained about one half of one per cent for uranium, as the Larmor voltage was varied from − 30 to − 2000 volts.

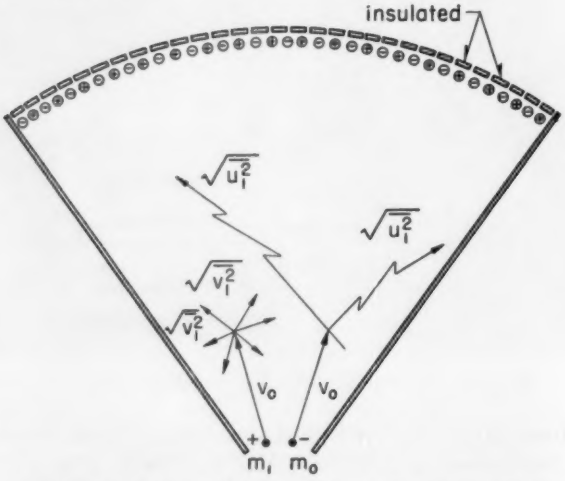

FIG. 4. Ionic gas, moving in (hypothetical) container. Reflecting walls (hypothetical).

Only after years of patient research, did we learn that neutralization of space charge was possible, only for very small currents with energy density of electrons very much smaller than the energy density of the positive ions.[6] When that small current was exceeded, rapid oscillations began, and a new set-up was reached wherein the random energies of the ions and electrons at any point of space became equal.

[6] J. R. Pierce, "Limiting Stable Current in Electron Beams in the Presence of Ions," *J. Appl. Phys.*, Vol. 15, pp. 721–726 (1944).

Here he treats of some special one dimensional cases of electron flow in a non-transverse magnetic field, and in the presence of "space-charge neutralizing" positive ions, of infinite mass. He finds that only some six times as great current can be carried smoothly in the presence of these "space-charge neutralizing" ions, as can be carried without space-charge neutralization.

When dealing with a transverse magnetic field, we may take the presence of "space-charge neutralizing" electrons, of *zero* mass, in directions perpendicular to the magnetic field. The current which may be carried smoothly by positive ions of finite mass transverse to the magnetic field, in the presence of these "space-charge neutralizing" electrons, will not be many times as great as the current which can be carried without space-charge neutralization.

Thus, the Calutron, which had electrons of low random energy neutralizing the space charge but not the current of a beam of ions, could only operate up to a rather low limit of ion current.

Now let us see how the Magneto-Ionic Expander works.

II. THE EXPANDER IS AN EXPANSION VESSEL

The Expander is merely an expansion vessel; the ions and electrons enter the small end, expand, and then precipitate at the large end. The side walls begin an inch or so from the arc and expand for a distance of two or three feet. To eliminate the effects of disturbing foreign gases, the Expander is maintained at a high vacuum free of such gases. To bring the ions and electrons from the immediate neighborhood of the generating arc to the mouth of the Expander, -10 or -20 volts are applied to the end walls of the vacuum vessel above and below the arc, extending to the initial end of the Expander.

A large number of ions and electrons will then be entering the Expander, Fig. 4; they will be equal in number, for there is no electrical connection to any object external to the Expander. At any point in space, they all will have the same mean random energy of motion or the same temperature, since the currents at which different mean random energies of the constituents may be supported will be far exceeded.

III. THE EXPANDER WITH NO MAGNETIC FIELD AND ZERO POTENTIAL DIFFERENCE—REFLECTING SIDE WALLS

Let the mean initial velocity of the ions and electrons be v_{00}, and the mean temperature be T_0, at any point taken as the beginning of the Expander. The mean velocity of the ions can only be about equal to the equivalent of its temperature there, since an enrichment of $\delta m/2m$ is all that could be obtained from the isotopes there. Hence,

$$\tfrac{1}{2}mv_{00}^2 = \tfrac{1}{2}kT_0. \tag{2}$$

A magnetic field and an electric potential impressed across the side walls function to keep the side walls free of any deposit, but, at first, it will serve our purpose better not to use a magnetic field, to employ zero potential difference, and to assume that the side walls reflect the ions and electrons with no loss of energy.[7] Since the random energies of the ions and electrons are more than 100,000° C., we see that this assumption is a purely temporary thing, and cannot be given the test of reality. The later addition of the magnetic field and electric potential to the side walls provides for the disappearance from them of precipitates of ions or electrons, and so permits the use of ordinary metals for them.

How about the end walls perpendicular to the field? Since they are

[7] This is a repetition of a section of Ref. (1), but since a small mistake was made in it, it is believed better to give it again.

remote from the originating arc, and if they are composed of small insulated pieces, the few ions and electrons they trap will do no harm. We can make the same assumption about these end walls as we do for the side walls, for the case we are considering.

With no magnetic field, no electric potential difference between the side walls, and with total reflection at the side and end walls, the ions and electrons will pass down the Expander, and they will precipitate as in Fig. 4 upon the final slats. Letting their final mean velocity and temperature be v_0 and T, we will have

$$\tfrac{1}{2}mv_{00}^2 + 5kT_0 = \tfrac{1}{2}mv_0^2 + 5kT = \tfrac{1}{2}mv_0^2 + 5kT_0\left(\frac{v_{00}S_0}{v_0S}\right)^{\frac{1}{3}} \qquad (3)$$

where S_0 and S are the initial and final cross-sections of the gas stream in its adiabatic motion through the Expander. In our Expander S_0/S is very small, and v_0 takes on a nearly constant value, equal to $\sqrt{11}$ times v_{00}.

The random velocities of the electrons and of the ions are given by

$$\tfrac{1}{2}kT = \tfrac{1}{2}m_0\overline{u_x^2} = \tfrac{1}{2}m_0\overline{u_y^2} = \tfrac{1}{2}m_0\overline{u_z^2} = \tfrac{1}{2}m\overline{v_x^2} = \tfrac{1}{2}m\overline{v_y^2} = \tfrac{1}{2}m\overline{v_z^2}. \qquad (4)$$

The energy of mean motion of the electron is negligibly small, and it is neglected in Eq. 3.

This reduction of temperature, in the adiabatic expansion of the gas, with the work done in increasing the energy of mean motion, is well known to those versed in fluid flow; it is less well known to the general physicist, although it is exemplified daily in the expansion nozzles of steam turbines.

IV. MAGNETIC FIELD AND LARGE ELECTRIC POTENTIAL DIFFERENCE BETWEEN SIDE WALLS

A magnetic field helps to prevent precipitation on the side walls (Fig. 5). A simple test demonstrates that a magnetic field alone deflects the ions toward one of the walls, say the right hand one. An electric field equal to $E_\theta = \frac{1}{c}Hv_0$ simultaneously applied will just keep the ion going straight out in its outward path, and also will keep the electron going straight out. But a potential difference strong enough to create this field at a more remote point, will give a larger field at a less remote point, and a current will flow away from the right hand side wall, towards the left hand side wall. The force exerted on this current of ions and electrons by the transverse field, H, will be radially outward.

At the left hand side wall, electrons are carried away into the ionized gas by the strong electric field, leaving almost nothing but positive ions to carry the current to the wall. But positive ions by themselves, in an electric field perpendicular to the surface of the side walls and in

the magnetic field will move outwards parallel to the surface of the side wall.

Likewise, electrons are left as a space charge before the right hand side wall, and in the electric field perpendicular to the surface and in the magnetic field, H, these electrons will be moved outwards parallel to the surface of the right hand side wall.

Thus, the current cannot close on the side walls, if the potential difference is large enough. If the potential difference is large enough, the current will turn just before reaching the well-insulated slats and close itself, within the ionized gas, causing a retardation in the ions and electrons it had previously accelerated.

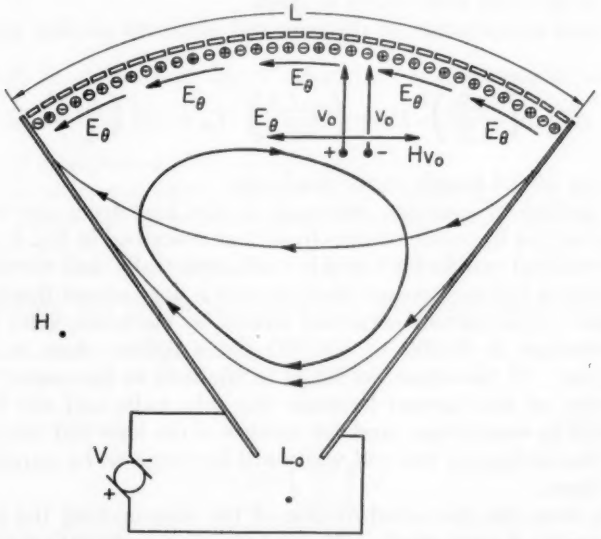

FIG. 5. Ionic gas, expanding in actual radial container. Gas is of two isotopes m_1 and m_2.

Curved arrowed lines are current lines of negligible magnitude.
Closed curve is of considerable magnitude.

Thus, we see that the combination of the magnetic field and a sufficiently strong potential difference between the side walls, will prevent condensation of the ions upon the side walls.

The end walls, set perpendicular to the magnetic field, are insulated and are set so far from the ion source, a short $\frac{1}{4}$-in. electric arc, that they collect few ions and electrons.

With a strong enough magnetic field and a strong enough potential difference between the side walls, practically all the ions and electrons fall upon the insulated final slats. T is nearly zero, and v_0 is $\sqrt{11}$ times v_∞, because of the large increase of section of the Expander.

V. SLAT POTENTIAL DIFFERENCES, ELECTRIC FIELD, AND TEMPERATURE, FOR ONE ISOTOPE—CIRCULATING CURRENT IN EXPANDER

The electric field just below the insulated slats will be

$$E_\theta = \frac{1}{c} H v_0, \tag{5}$$

and the electric potential difference between the first and last slats will be

$$V = -LE_\theta = -\frac{1}{c} LHv_0 \tag{5''}$$

where L is the final total width of slats.

The final temperature of the ions and electrons as they precipitate will be

$$T = \left(\frac{v_{00}S_0}{v_0 S}\right)^{\frac{1}{3}} T_0 = \left(\frac{v_{00}L_0^2}{v_0 L^2}\right)^{\frac{1}{3}} T_0 = 11^{\frac{1}{3}} \left(\frac{L_0}{L}\right)^{\frac{1}{3}} T_0 \tag{6}$$

with L_0 the initial length of the discharge.

The motion of ions and electrons in the part from the beginning to the end of the Expander differs from that described in Eq. 3, although the net material caught on the side walls, end walls, and terminal slats is the same as before, because there is now a net current flowing round in the gas. This current is carried mostly by electrons, since the mass of the electron is 10,000 to 500,000 times lighter than that of the positive ion. If, therefore, we let H be the field in the center, the field at the edge of the current between the side walls and the Expander proper will be even larger, and the motion of the ions and electrons just outside the surface of the end walls will continue to be parallel to the surface there.

Then since the disturbed motion of the ions making the ionic part of the current is very small, and since the first acceleration of the ions by the current is compensated for by a later deceleration, then the ions and electrons arrive at the slats with the same velocities, Eq. 3, and the same field, potential, and temperature, Eq. 4, which they would have had in the hypothetical case of perfect reflection from the side walls, and no magnetic field.

VI. TWO ISOTOPES IN EXPANDER

Now we consider the case where the gas has two isotopes, masses m_1 and m_2, passing together up the Expander. How will the isotopes influence each other? The magnetic field will give an effect on the ions proportional to the momentum of the ions, whereas the electric field and bounding walls give an effect proportional to the kinetic energy of the ions.

Consider the one isotope m_1, all alone, passing up the Expander. There will be at every point a certain mean velocity, v', and an electric field, E'. We will not have $E' = \frac{1}{c}[Hxv']$ at every point, because at the various points there will be a current there. But finally, just before the insulating slats, we will have

$$E_\theta' = \frac{1}{c} H v_0' \tag{7'}$$

and a temperature

$$T = 11^{\frac{1}{3}} \left(\frac{L_0}{L}\right)^{\frac{1}{3}} T_0. \tag{6}$$

E_θ' will be determined by v_0' which is entirely determined by the energy relation, Eq. 3. $E_1' = \frac{1}{c}[Hxv']$ will be determined by both the energy and momentum of the ions of mass m_1.

Now consider the other isotope m_2, all alone, passing up the Expander. There will be at every point a certain mean velocity, v'', and an electric field E''. Again, we will not have $E'' = \frac{1}{c}[Hxv'']$ at the various points, but finally just before the insulating slats we will have

$$E_\theta'' = \frac{1}{c} H v_0'' \tag{7''}$$

and the temperature

$$T = 11^{\frac{1}{3}} \left(\frac{L_0}{L}\right)^{\frac{1}{3}} T_0. \tag{6}$$

Again, E_θ'' will be determined by v_0'' which is entirely determined by the energy relation, Eq. 3. $E_1'' = \frac{1}{c}[Hxv'']$ will be determined by both the energy and momentum of the ions of mass m_2.

Now suppose the two isotopes m_1 and m_2 are both present in the gas. Suppose $m_1 < m_2$, $v_0' > v_0''$.

Now there can be but one electric field at a point, and we must have

$$-E_\theta' > -E_\theta > -E_\theta'' \tag{8}$$

at any point just short of the slats. Therefore, there can be but one, v_θ, a mean velocity at which both ions approach any particular slat,

$$v_0' > v_0 > v_0'', \tag{9}$$

that is, the lighter, faster ion, m_1, is compelled to approach the slat, by the reactions of electrons which have reacted with m_2, with a velocity v_0 which is less than its normal velocity v_0'. It follows then that it will be driven to the left by the magnetic field with a velocity w_1 (Fig. 6).

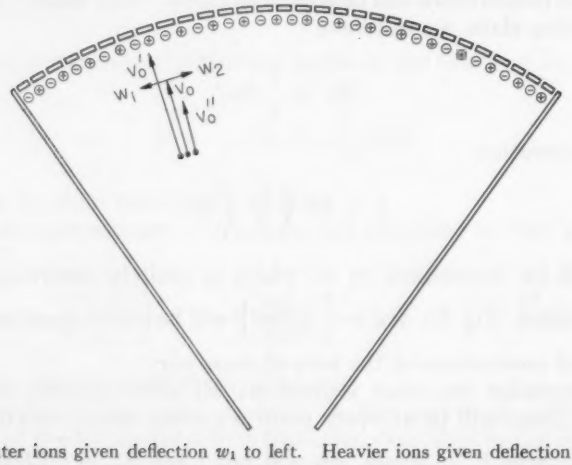

FIG. 6. Lighter ions given deflection w_1 to left. Heavier ions given deflection w_2 to right.

And the heavier, slower ion, m_2, is compelled to approach the slat, by the reactions of electrons which have reacted with m_1, with a velocity v_0 which is greater than its normal velocity, v_0''. Hence, it will be driven to the right by the magnetic field with a velocity w_2.

We see then that in the magnetic field the lighter particle will move to the left, and the heavier to the right. There will be enrichment of the lighter particles on the slats on the left; there will be enrichment of the heavier particles on the slats on the right.

E' and E'' will also need to reduce to a single electric force E at points within the Expander. The result will be a mutual influencing of the effects of the isotopes upon each other, since the momenta and energy of the two ions do not remain in constant proportions, as the gas expands.

In the direction parallel to the magnetic field, the electrons will be travelling up and down with random velocities which are hundreds of times greater than the random motions of the positive ions, and thus the two ions will always have the same temperature at the same point. While the mutual effects of the ions upon each other will not be simply additive, we may still expect the residual effect of the common journey after cancelling the decelerating effect from the accelerating effect of the current upon the ions to be

$$w_1 - w_2 = \frac{L}{2L_0} v_0 \frac{\delta m}{m} \tag{10}$$

with w_2 small on left hand slats or with w_1 small on right hand slats.

We therefore expect the slats at the left to be enriched with the light ion in proportion to the square of L/L_0. With L_0 taken as 1 in., L may be taken as 50 in. to make the enrichment equal to 2500 $\frac{\delta m}{2m}$ which means practically pure isotopes in one single operation even for the heavy metals.

VII. THE MAGNETO-IONIC EXPANDER ISOTOPE SEPARATOR

The potential used between the final slats in the Expander may amount to several hundred volts, but the energy of the precipitating ions is only about ten volts. Unlike the Calutron, or mass spectroscope in which the deposit of metal is, for uranium, at 50,000 volts, the metallic deposit is easily stripped from the ion bearing slats.

The energy spent in the arc gave grams of uranium deposit per kilowatt-hour. This was obtained with a 100-amp. arc giving 10 amp. of uranium ions. How much larger current may be used is as yet not known. There is no limit due to induced oscillations, since we are in the limiting case where the energy of random motion of the positive ions is equal to the energy of random motion of the negative electrons. Probably the limit will come where the heat of precipitation will become excessive.

The percentage of neutral material given off in the arc is exceedingly small, far less than 5 per cent. This compares with several hundred per cent given off in the Calutron.

The intensity of magnetic field should be high enough to require a voltage of 10 or 20 volts to bring the discharge up to the beginning of the Expander, when the side walls are open circuited, and the end walls over the Expander are open circuited. Use of a greater magnetic field than this merely raises the voltage of the discharge, without giving any larger enrichment.

Aligning Atomic Nuclei.—The alignment of atomic nuclei is of great importance in many areas of research in nuclear physics. Nuclei have only very small magnetic moments, however, and it at first appeared that extremely high magnetic fields or extremely low temperatures would be required to produce any appreciable nuclear orientation.

A means of escape from this situation was indicated by Overhauser who showed in 1953 that under certain conditions electronic paramagnetic resonance absorption can be employed to enhance the degree of nuclear polarization. George Feher of Bell Telephone Laboratories has recently made another significant advance in this field of research by his development of a powerful new technique for aligning nuclei. His process employs both electronic and nuclear paramagnetic resonance absorption.

Interaction of the electronic and nuclear magnetic moments in an atom leads to splitting of its electronic energy levels. The resulting hyperfine levels are further split by an external magnetic field, but this field splitting is not the same for two adjacent hyperfine levels and this is fundamental to Feher's novel process of nuclear alignment.

Because of the unequal field splitting, nuclear transitions in only one of the two resulting sets of hyperfine levels can be produced by absorption of selected radio frequency quanta. Such transitions involve a change of nuclear spins, or a spatial reorientation of nuclear magnetic moments, and this leads to nuclear alignment.

The new scheme of nuclear polarization is unique in that it places no requirements on the relaxation mechanism for either nuclei or electrons except that the relaxation times be quite long. It is only necessary to sweep through a fraction of the applied magnetic field in a time short compared to either relaxation time. The combined action of this swept field and a microwave magnetic field induces allowed electronic spin resonance transitions between the two sets of hyperfine levels. These transitions produce changes in level population such that each set of hyperfine levels exhibits a nuclear polarization. However, the alignment in one set is opposite to that in the second, so that the sample as a whole is not yet polarized.

With the sample in this state, the nuclear polarization of just one of these sets is reversed by nuclear resonance absorption in a radio frequency magnetic field of the proper frequency. This results in nuclear alignment which is the same in both sets, so that nuclei in the sample as a whole are similarly polarized and the specimen possesses a microscopic nuclear magnetic moment.

Under certain conditions the changes in population of hyperfine levels produced by this nuclear resonance absorption result in pronounced changes in the electron resonance absorption intensities. Observation of the electron spin resonance line thus provides a very sensitive means of studying nuclear resonance phenomena.

This new double frequency resonance technique not only facilitates study of nuclear transitions but also permits determination of hyperfine interaction constants and nuclear gyromagnetic ratios. It is applicable in those cases where the hyperfine interaction is small compared to the electron line width so that hyperfine structure cannot be resolved by the usual single frequency spin resonance technique. Through its use new information is being obtained on impurities in semiconductors, on F centers in alkali halides, and on values of the electron wave function at various lattice points in solids.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS

FIRE DETECTION IN AIRCRAFT ENGINE SPACES

When fire breaks out in an aircraft engine space, it must be detected and quenched within seconds to avoid serious damage or possible loss of life. To provide design specifications for reliable, fast-acting fire detectors, the National Bureau of Standards has been studying[1] flame characteristics that might be applied to aircraft fire detection systems. Results of this work indicate that reliability could be greatly increased by a system that would not respond unless several intrinsic properties of a flame were all present at the same time. These properties are (1) characteristic rate of increase of radiant flux, (2) sufficient level of radiant flux in the required spectral region, and (3) characteristic frequency of flicker. The investigation was undertaken for the Wright Air Development Center by W. F. Roeser and C. S. McCamy of the Bureau's fire protection laboratory.

Too often in the past, frequent false alarms have undermined the airman's confidence in his fire detector, causing him to hesitate or neglect to take action when an alarm sounded. In some instances fires were not detected or were detected too late. Flight experience and fire tests under simulated flight conditions have clearly indicated that to be effective, a fire detector must invariably respond if, and only if, there is a fire and it must do so as quickly as possible.

Detectors are required to discriminate between fires and other phenomena under the most adverse environmental conditions, including temperatures from $-65°$ to over 500° F., wind speeds over 500 mph., rain, hail, fog, salt spray, dust, oil, grease, fungus, fumes, vibration, and extreme pressure changes. A detector designed to respond to the radiant energy from flames, for example, must discriminate between flames and sunlight, lightning, gun-fire, or beacons. The detector must survive a fire with flame temperatures over 2000° F. so that it can indicate that the fire is out and be ready to detect another fire a short time later. The aircraft designer demands that detectors have the least possible size and weight.

A survey of existing or proposed systems revealed a number of ingenious applications of various physical principles. Radiant energy detectors seemed the most promising because a single detector can monitor a large space. However, for development of improved designs,

[1] For further technical details, see "A Five-Band Recording Spectroradiometer," by C. S. McCamy, *J. Res. NBS*, Vol. 56, (1956) RP 2678; "Principles of Fire Detection in Aircraft Engine Spaces," by W. F. Roeser and C. S. McCamy (may be purchased from the Office of Technical Services, Department of Commerce, Washington 25, D. C., price, $3.00).

more fundamental data were needed on the characteristics of flames involved in aircraft engine fires. Therefore, a study was undertaken at the National Bureau of Standards of the radiation and flicker of flames.

FLAME SPECTRA

The more important flammable materials found in aircraft engine spaces include such liquid hydrocarbons as engine fuel, lubricating oil, and hydraulic fluid. In a typical engine fire involving these flammable liquids, oxygen diffuses into the flames from the surrounding atmosphere, producing a "diffusion flame" which emits essentially the same continuous spectrum for each of the burning liquid hydrocarbons. Experiments were performed which showed that various aircraft fuels premixed with air before burning produced nearly identical spectra except for the lead lines in the spectra of leaded fuels. As a result of these spectrometric studies it was concluded that for the design of radiant energy detectors the same spectral region would be suitable for all fuels likely to be involved.

RADIATION MEASUREMENTS

The radiant intensities of the flames of various fuels were measured in five wavelength intervals from 0.24 micron in the ultraviolet to 2.5 microns in the infrared. To measure the fluctuating radiant intensity in all parts of the spectrum simultaneously, photoelectric detectors were used with suitable filters and the output signals were recorded on a multichannel recording oscillograph. A radiation-pyrometer detector with appropriate filters measured the radiance of flames in several infrared regions extending to 9.5 microns.

The investigation showed that flames of the type likely to occur in engine spaces emit energy throughout the spectrum but emit far more in the near infrared than in any other wavelength region. Some parts of the spectrum were found to be unsuitable for use in fire detection. The strong absorption of radiant energy by oil, grease, and soot in the visible and ultraviolet parts of the spectrum would prevent reliable detection of energy of those wavelengths. The visible part of the spectrum is also considered undesirable because of the high intensity of sunlight and skylight in that region. The most suitable part of the spectrum for fire detection therefore appears to be the near infrared.

The characteristics of various window materials were considered with respect to ambient conditions and their effects on discrimination. Of the materials capable of withstanding the ambient conditions expected, fused quartz appears to be the most satisfactory since it transmits well in the infrared out to about 3.8 microns. Moreover, it transmits a somewhat larger percentage of the energy from flames than from a hot metal background having the same radiance as a flame, thus providing a measure of discrimination between these sources.

INCREASE IN RADIATION

Although the engine radiance may approach that of a flame, the engine takes a much longer time to heat up than the fuel vapors take to burst into flame. Measurements show that the flames to be expected in accidental fires in engine spaces reach full intensity about a quarter of a second after ignition, while the engine takes over a minute to warm up. This difference in rate of increase of radiation provides another distinguishing feature for detection purposes.

FLICKER MEASUREMENTS

A high level of radiant flux or a rapid rate of rise could be caused by events other than fires. One of the recognized attributes of flames is their natural tendency to flicker—to produce a fluctuating radiant intensity. This effect occurs simultaneously in all parts of the spectrum studied. The nature of flicker was observed with high-speed motion pictures and electronic wave analysis of the output of photoelectric detectors.

The motion picture measurements indicate that variation in projected flame area rather than variation in radiance accounts for a large part of the flicker of flames. Electronic wave analysis provided flicker amplitude distribution curves for the various flames studied. In many cases, these curves have a sharp maximum at some frequency between 3 and 15 cps. The ratio of the rms flicker amplitude to the average radiant intensity for various flames ranges from about 0.1 to about 0.4 for burning liquids. These results indicate that flicker provides another valuable distinguishing feature for detector design. Since moving engine parts or other periodic phenomena might cause fluctuations in the radiant flux, flicker was not recommended for use alone as a fire detector, but rather in combination with the characteristic rate of increase of radiant flux and sufficient radiant intensity in the right spectral region.

POROSITY DETECTION IN PLATED COATINGS

Pores and other flaws seriously impair the quality of industrially produced electroplated coatings, diminishing their effectiveness as protective coatings for metals. Until now it has been difficult to estimate the relative merits of electrodeposits since no method of determining the gravity of defects was available. Recently, however, the National Bureau of Standards has developed a non-destructive procedure for ascertaining both the size and position of pores.[1] The method involves photographing an electroplated specimen exposed to radiation.

[1] "The Nature, Cause and Effect of Porosity in Electrodeposits, II. Radiographic Detection of Porosity in Electrodeposits," by F. Ogburn and M. Hilkert, Annual Tech. Proc. Amer. Electroplaters' Soc., p. 256 (1956).

In earlier research, a technique applicable to plated coatings that have been removed from the basis metal was developed by the Bureau.[2] However, the likelihood of stripped-coating porosity differing from adherent-coating porosity led to further investigation of the problem. The present work was carried out for the American Electroplaters' Society by F. Ogburn of the Bureau staff and Margaret Hilkert of the Society's research fellowship at the Bureau.

In determining the location and size of pores, the specimen, a flat sheet of plated metal a few thousandths of an inch thick, is placed on a photographic film with the coating against the film emulsion. The assembly is held in a cardboard cassette, and the basis-metal side of the specimen is exposed to X-rays or radiation from a radioactive material. To insure good contrast, the X-radiation used must be soft. This requirement of low-energy X-rays limits the thickness of the basis material to several thousandths of an inch, since thicker metal absorbs too much of the X-ray beam and requires too long an exposure time. Radioactive iron, nickel, or cobalt held against the plated specimen in a cassette are also adequate sources of radiation.

After a suitable exposure time the film is removed and developed. Satisfactory radiographs result from a 3- or 4-min. exposure to an X-ray machine, and from a 24-hr. exposure to 1 μc of radioactivity. Wherever a pore existed in the coating, a black spot appears on the developed film. A fine-grain industrial X-ray film gives the most readable radiograph.

This radiographic method detects pits, voids, and inclusions in the coating to the order of 0.001 in. in diameter. Discontinuities in the basis metal may also be determined by radiographing the metal before plating.

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[2] "The Nature, Cause, and Effect of the Porosity in Electrodeposits," by F. Ogburn and A. Benderly, *Plating*, Vol. 41, p. 168 (1954).

THE FRANKLIN INSTITUTE

MINUTES OF THE ANNUAL MEETING

January 16, 1957

The Annual Meeting of The Franklin Institute was held on Wednesday, January 15, 1957, in the Lecture Hall. S. Wyman Rolph, President, called the meeting to order at 8:15 p.m., with approximately 360 members and guests in attendance.

The President stated that the minutes of the December Stated Meeting had been printed in the January JOURNAL of The Franklin Institute; there being no corrections, changes or additions, they were approved as published.

Mr. Rolph then asked for the report of the Tellers appointed in accordance with the By-Laws to count the votes for the eight Managers to be elected. George Crampton, Chairman reported that 1,052 ballots were received, of which 1,025 were legal and 27 defective, and that the nominees received votes as follows:

Brandon Barringer	1,018	Charles S. Redding	1,023
Edward G. Budd, Jr.	1,017	John Russell, Jr.	1,018
James McGowan, Jr.	1,025	W. Maxwell Scott, Jr.	1,015
Richard T. Nalle	1,018	I. Melville Stein	1,020

The President declared that the above members were thereby elected Managers of The Institute for a term of three years and thanked George Crampton, Joseph Hepburn, Howard Stoertz for their services.

As required by the Deed of Gift which forms the basis of the award of the Elliott Cresson Medal, the Assistant Secretary read the following report submitted by the Trustees of the Elliott Cresson Medal Fund showing the financial transactions for the year:

ELLIOTT CRESSON MEDAL FUND

Report of the Trustees to The Franklin Institute

January 16, 1957

Principal of the Fund (representing the original $1,000 plus transfers thereto from Unexpended Income and profit from disposition of investments)		$4,304.73
Invested as follows:		
$4,000 U. S. Treasury 2½% bonds, due 6/15/1962–67 at book value	$4,086.91	
Cash in Western Savings Fund Society	217.82	
	$4,304.73	
Income of the Fund for 1956		
Interest on bonds (less amortization)	$ 126.29	
Interest on bank balance	5.25	$ 131.54
Expenses		
Insurance of medal dies for period of one year		5.37
Income for the year		126.17
Unexpended income at January 1, 1956		2,233.48
Unexpended income at December 31, 1956		$2,359.65

Invested as follows:

$2,000 U. S. Treasury 2¼% bonds, due 6/15/1962–67 at book value	$2,043.68
Cash in Fidelity-Philadelphia Trust Company	315.97
	$2,359.65

(s) *Henry B. Allen*
HENRY B. ALLEN

(s) *John Fraser*
JOHN FRAZER
Trustees

After presenting a brief summary of The Annual Report, the President stated that the full report is to be published in the March issue of the JOURNAL.

Mr. Rolph then presented the speaker of the evening, Dr. W. F. G. Swann, who gave a very able talk entitled, "Reality, Imagery and Fantasy." which will be published in a later issue of the JOURNAL.

The meeting adjourned at 9:43 p.m.

C. M. WATERBURY
Assistant Secretary

MEMBERSHIP

ACTIVE MEMBERS ELECTED BY THE BOARD OF MANAGERS

January 16, 1957

ACTIVE FAMILY

Frederick H. Clash, Jr.
Alexis Irenee duPont
Joseph A. Garay
Giovanni Luciolli
Harry Lyster
Alexander Mackerell
Louis Makransky
John F. McGinnis
Arthur Rosenberg
George O. Rudkin, Jr.
J. Kenson Simons

ACTIVE

Carl R. Brandt
Emerson L. Bray
W. B. DeLong
Arthur C. Hontz
Daniel L. Horigan
Harry Hyde, Jr.
John F. Kovach
Bernard Kress
John Kurmer
Joseph W. Riley
E. Leslie Snow

ACTIVE NON-RESIDENT FAMILY

Charles D. Snelling

ACTIVE NON-RESIDENT

William Grobman

NECROLOGY

P. T. Dashiell '17
W. R. Hughes, Jr. '45
Stanton C. Kelton '48
C. J. Kern '42
George M. Kohn '50
Otto Todd Mallery '54
Mrs. Belle S. Starsmann '53
Joseph H. Sykes '45
Leo Wallerstein '16
Douglas R. Warfield '36

COMMITTEE ON SCIENCE AND THE ARTS

(Abstract of Proceedings of Stated Meeting held Wednesday, January 9, 1957.)

HALL OF THE COMMITTEE,
PHILADELPHIA, JANUARY 9, 1957.

MR. FRANCIS B. FOLEY in the Chair.

The following reports were presented for final action:

No. 3274: The Carbon-14 Method for the Determination of the Age of Relics and Remains of Antiquity.

This report recommended the award of an Elliott Cresson Medal to Willard Frank Libby, of Chicago, Illinois, "For his painstaking development of the logic and technique of radiocarbon dating whereby the age of samples of carbon of organic origin may be measured, and for his extensive application of the method to the establishment of a valid world-wide chronological scale."

No. 3305: Clamer Medal.

This report recommended the award of the Francis J. Clamer Medal to William G. Pfann, of Basking Ridge, New Jersey, "In recognition of his discovery and application of zone refining to metals and other crystalline substances."

DELMER S. FAHRNEY,
Secretary to Committee

PRESENTATION OF NEWCOMEN MEDAL

January 18, 1957

The following remarks were made by Coleman Sellers III, in presenting Colin Campbell Mitchell for an award of a Newcomen Medal. The presentation took place Friday, January 18, 1957, at the Newcomen Society Dinner in Franklin Hall:

COLEMAN SELLERS III: Mr. President, I present Colin Campbell Mitchell for an award.

The principle of the catapult had its origin in antiquity. We read of the use of catapults to breech the walls of cities under storm many hundreds of years ago. After all, the bow and arrow is a form of catapult and so is the rubber band sling shot which we used, and sometimes mis-used, in our youth. Over the centuries the fundamental principles of the catapult have not changed. The sources of energy, however, have been many and varied.

When aircraft carriers were first conceived and built, the planes they carried were of a size and weight that could be operated and taken off the deck under their own power. As these planes increased in weight it became necessary to find means of accelerating them in order to keep the length of the carrier deck to reasonable proportions. Hydraulically operated catapults were utilized successfully with, however, complicated cable mechanisms and very high pressure cylinders to produce the energy. These operated successfully during World War II and the Korean War, but the advent of jet aircraft produced power requirements and acceleration specifications that the hydraulic mechanism could not be efficiently designed to meet.

Gunpowder, as an energy source, was considered, but the fire hazard and other technological problems were not easy to overcome.

Our Medalist solved the problem by his invention of the steam actuated catapult utilizing the steam supplied by the ship's boilers. The key to the successful application of steam to the catapult was his ingenious conception of a means of sealing a slot in a long cylinder after the piston and connecting link to the airplane had passed, thereby containing the steam in the cylinder behind the piston.

When Newcomen developed his steam engine, he could hardly have envisioned the use of a cylinder and piston with steam behind it to throw aircraft carrying men into the air at speeds of 150 miles per hour or more. However, both the Navies of Great Britain and the United States have universally adopted our Medalist's catapult with some carriers already equipped and more to follow.

I present Colin Campbell Mitchell, of Edinburgh, Scotland, as a candidate for The Newcomen Medal, "In consideration of his design and development of a steam catapult which makes possible a safer, faster, and more powerful method of launching aircraft."

LIBRARY

The Committee on Library desires to add to the collections any technical works that members may wish to contribute. Contributions will be gratefully acknowledged and placed in the Library. Duplicates received will be transferred to other libraries as gifts of the donor. 447 items have been added the past month.

Photostat service. Photostat prints of any material in the collections can be supplied on request.

The Library and reading room are open from 9 A.M. until 5 P.M. on Mondays, Tuesdays, Thursdays, Fridays and Saturdays; and from 2 P.M. until 10 P.M. on Wednesdays.

RECENT ADDITIONS

AERONAUTICS

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JOURNAL OF THE FRANKLIN INSTITUTE

The following papers will appear in this JOURNAL within the next few months:

COULSON, THOMAS: Some Prominent Members of The Franklin Institute. No. 4. Coleman Sellers. 1827–1907.

PIPES, LOUIS A.: Matrix Analysis of Heat Transfer Problems.

BOLINDER, E. FOLKE: The Classical Electromagnetic Equations Expressed as Complex Four-Dimensional Quantities.

MADAN, MAHENDRA P.: Simple Bridge Method for the Measurement of Thermal Conductivity of Gases and Gas Mixtures.

WEAVER, WARREN: Radiations and the Genetic Threat.

PENFIELD, R. H. AND H. ZATZKIS: Quantization of the Relativistic Harmonic Oscillator by Perturbative Methods with Applications to Van der Waals Forces.

HU, L. W.: Analysis of Die Profiles in Wire Drawing.

BEKKER, M. G.: Present State of Off-Road Locomotion and Its Future.

GREENSPAN, DONALD: On a "Best" 9-Point Difference Equation Analogue of Laplace's Equation.

NOTES FROM THE FRANKLIN INSTITUTE MUSEUM

A. C. CARLTON, DIRECTOR

PROGRESS IN THE AIR

Some of man's greatest inventions, like the wheel, have no counterparts in nature, while others are copied directly from nature but are far removed from the original source from which they were derived. The phenomenon of natural flight was, of course, the inspiration for the idea of human flight, but the man-made machines to obtain propulsion differ entirely from those of the birds.

A good many methods have been tried to provide a heavier-than-air machine with the power to leave the ground, but it was not until the arrival of the internal combustion engine that there was a prospect of success. Now we have arrived at the stage where the conventional design of this engine is being abandoned. Recently, visitors to the Museum had the opportunity of seeing how the turbo-jet engine operates in one of the latest designs, and now a new conception is being displayed to keep visitors in step with aviation progress.

This new concept is the Rolls-Royce turbo-prop engine, four of which are installed in the new Viscount airliner. The operation of the engine is clearly shown in the cut-away example on display. The operating cycle shows how air is drawn into the engine through a ring-shaped intake and led into a two-stage compressor. The compressed air is forced to seven combustion chambers where it is mixed with a low volatile kerosene and ignited. The tremendous energy thus created is utilized to drive a two-stage axial turbine. The turbine power is transmitted by a shaft to drive the compressor and then through a high ratio reduction gear to drive the propellor. The result furnishes a silent smooth flight that is almost completely free from vibration.

By way of contrast, and to show the enormous progress made in the development of power within the past forty years, an original three-cylinder Anzani engine is displayed alongside the big Rolls-Royce. The tiny Anzani furnished the motive power on Louis Bleriot's famous flight across the English Channel in 1909. This narrow strip of water had been crossed by balloon in 1785, a very notable adventure, but the crossing by airplane was of greater significance because it proved the "flying-machine" was at last a practical vehicle. The psychological effect of this flight could not be denied, and it has been selected by general consent as a landmark in progress.

The Anzani was air-cooled, but so precarious was this flight that its power was only just sufficient for the task, and it is said that had Bleriot

not passed through a shower of rain, which helped to cool his engine, he would never have reached the English coast.

The display of the Rolls-Royce engine falls at an appropriate time to mark the two interesting fiftieth anniversaries that are celebrated this year. It is just fifty years ago since Santos Dumont made the first heavier-than-air flight in Europe. It was not a very long flight, for the adventurous pilot was airborne for no longer than eight seconds.

Although the Wright brothers had made their first flight in 1903, it was not until December of 1906 that their first patent was issued. A visit to the Aviation Section in order to see the latest advance in air progress will enable the visitor to make acquaintance with the precious mementos of the Wright brothers' early efforts to attain a suitable design for aircraft. The original material bequeathed by the late Orville Wright to the Institute makes apparent the calculated scientific approach the brothers made to their purpose, and nothing could show more convincingly that they were much superior to the two bicycle mechanics they are popularly presented as being.

The Museum is indebted to the enterprising Capital Airlines for making the Rolls-Royce engine available for display to its visitors.

BARTOL RESEARCH FOUNDATION
W. F. G. SWANN, DIRECTOR

SEA-GOING COSMIC-RAY OBSERVATORY

BY
MARTIN A. POMERANTZ

A complete cosmic-ray map of the world is to be prepared in a long range program in which The Bartol Research Foundation is participating with support from several organizations. Apparatus for this survey has been put aboard the Swedish merchant vessel *M/S Lommaren* plying between Sweden and South Africa. The sea-going observatory is being operated as part of the International Geophysical Year Program in a collaborative effort involving The Bartol Research Foundation, the National Research Council of Canada, and the Fysiska Institutionen of Uppsala University, Sweden. The neutron monitor on board, which weighs some three tons, was constructed at Bartol.

This cosmic-ray map will show the variation in the intensity of cosmic-rays over the earth's surface. This variation comes about through the interaction of the primary cosmic-ray particles with the magnetic field of the earth.

Although the external magnetic field of the earth is relatively weak, its influence extends for very great distances far beyond the upper reaches of the atmosphere. Consequently, electrically-charged particles travelling towards the earth from distant sources such as the sun follow trajectories which are not straight lines, owing to the well-known fact that such bodies suffer a deflection while moving in a magnetic field. Actually, incoming atomic particles of a specific type must possess a certain minimum speed in order to reach the earth at all near the geomagnetic equator, where the magnetic force is strongest. This velocity requirement is reduced as the poles are approached.

A detailed knowledge of the nature and properties of the external geomagnetic field is evidently of great interest not only intrinsically, but also because of its direct influence upon the unceasing atomic bombardment to which the earth is subjected. This is a matter of considerable practical interest in the subject of telecommunications, for example, since it is well-known that the state of the ionosphere, of paramount importance in long-distance radio reception, is governed by radiations emanating from the sun.

EARTH'S MAGNETISM AND COSMIC RAYS

Heretofore, it has been possible to describe the external geomagnetic field only on the basis of measurements obtained all over the world at or relatively near the surface. Thus, local anomalies such as concentrations of magnetic materials in the earth's crust which would produce

negligible effects at great distances can lead to large inaccuracies. Inasmuch as the theory of the motion of charged particles in the earth's magnetic field is well understood, and has been subjected to detailed mathematical analysis, it was natural to consider the possibility of utilizing the incoming cosmic rays as "sounding lines" for locating the geomagnetic coordinates. For it has been well established that the primary cosmic radiation is composed predominantly of protons (hydrogen nuclei), plus an appreciable percentage of alpha-particles (helium nuclei), and a few per cent of heavier nuclei, all stripped of their outer electrons and hence carrying a net electrical charge.

Actually, it has been established from surface measurements that the earth's magnetism is equivalent to that which would be produced by a small bar magnet displaced somewhat from the geographic center of the earth, with its north pole pointing approximately to 80° N and 83° W, and its south pole intercepting the surface at approximately 76° S and 121° E. Two principal effects upon the cosmic radiation are produced by the magnetic field associated with this equivalent eccentric dipole. In the first place, the intensity, that is the number of particles which would be recorded by a particular detector each minute, is minimum at the geomagnetic equator, and increases as the detector is moved either northward or southward towards the pole. This variation of intensity with position along a meridian is called the latitude effect.

Secondly, a longitude effect which is greatest at the equator is also observed. This arises from the fact that the magnetic center is displaced approximately 340 kilometers from the center of the globe. It is evident that, from measurements of the cosmic-ray intensity as a function of latitude and longitude, it is possible to locate the magnetic equator and poles, and to determine the eccentricity of the dipole, that is, its distance from the center of the earth.

NEUTRON MONITOR PILE

Although, in principle, techniques for obtaining the desired cosmic-ray data have existed for many years, a rather fundamental limitation stemmed from the fact that all of the available methods of measurement were confined to the so-called hard component of the cosmic radiation (mesons) which manifests only a small variation with latitude, particularly in the crucial equatorial region. Furthermore, because these particles are unstable, and disintegrate a short time after they have been produced in interactions between the primaries and the atmosphere at very high altitudes, their intensity near sea level depends in a very complicated way upon continually-changing meteorological conditions throughout the atmosphere up to their point of origin. However, largely as an outcome of the beautiful work of Dr. John A. Simpson and his group at the University of Chicago, a new method of measurement has been developed during the last several years which takes advantage

of the fact that the nucleonic component, consisting of protons and neutrons produced in the atmosphere by the incoming cosmic rays, does not display such an effect, and, furthermore, manifests a much greater dependence upon latitude. Hence, considerably greater precision is now attainable.

The basic arrangement for measuring the intensity of the nucleonic component is shown in Fig. 1. A pile consisting of lead and paraffin

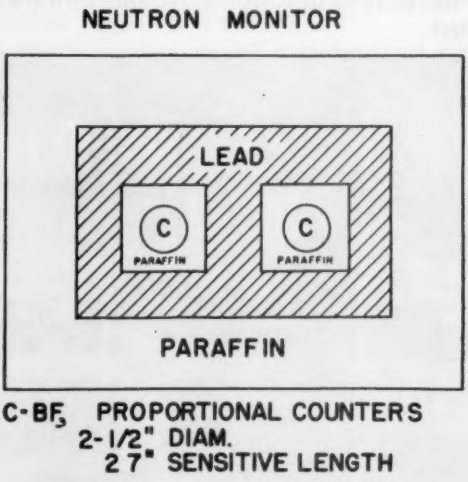

FIG. 1. Diagram of neutron monitor pile.

combines a material of high atomic weight in which incoming nucleons can interact, thereby producing a number of neutrons in each nuclear explosion, with a neutron moderator which slows these disintegration products down, and retains them until they ultimately pass through one of the proportional counters which serve as neutron detectors. In some respects, this structure, called a neutron monitor pile, resembles an atomic reactor, except that in this case, the nuclear fuel is the cosmic rays.

SHIPBOARD OBSERVATORY

From the data collected during voyages such as that of the *M/S Lommaren* over many sea routes, a plot of isocosms, that is, lines of constant cosmic-ray intensity, will be made. These isocosms also correspond to lines of equal magnetic field strength.

Actually, at geomagnetic latitudes north and south of approximately 55° N and S, respectively, the cosmic-ray intensity as observed with a detector of this type is constant for rather technical reasons involving the characteristics of the energy spectrum of the incoming cosmic radiation. It has therefore been feasible during a cruise to Baltic ports

prior to the present sailing to calibrate the monitor against an installation identical in all essential details which has already circumnavigated the North American continent aboard the ice-breaker *HMCS Labrador*, and has travelled to Antarctica and return on the *USS Atka* in a program under the direction of our Canadian associate in this project, Dr. D. C. Rose. Preliminary results have indicated a remarkable degree of reproducibility, and the data obtained with the present instrument will therefore be directly comparable with the measurements already completed.

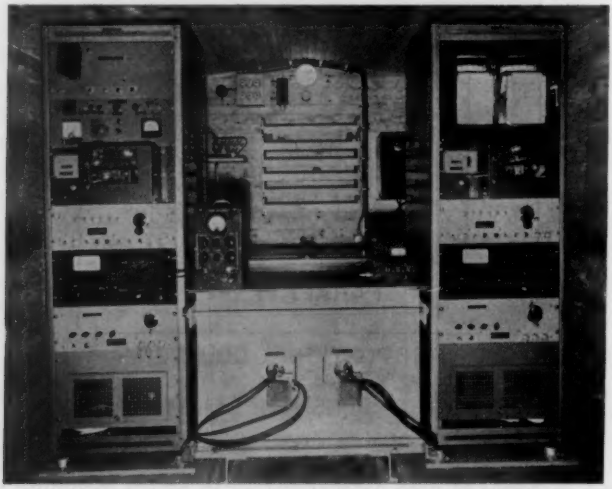

FIG. 2. Neutron monitor installation aboard *M/S Lommaren.*

Figure 2 shows a general view of the neutron monitor currently in operation aboard the *M/S Lommaren.* The pile, located in the center, is comprised of lead plates and aluminum tanks filled with paraffin. Each of the two counters containing BF_3 gas enriched with B^{10} actuates completely independent electronic circuits, so that the failure of any single component is easily recognizable. The counts, which average approximately 90 per minute for each counter at high latitudes, are scaled, after appropriate amplification and pulse-height discrimination, by a factor of 64. The scaled counts are tallied by a printing numerical register, as well as by an operation recorder pen which enters a pip on each of the two continuously-moving charts in the graphic recording instrument in the right-hand cabinet. A chronometer with electrical contacts causes the reading on the register, and the corresponding time, to be printed on tape every 15 minutes. The impulses from both counters are also combined and introduced into a counting-rate computer, which indicates the average number of counts per minute. This is recorded on a chart continuously moving at a speed of six inches

per hour, thereby making it possible to correlate the time-variation of any unusual changes in the cosmic-ray intensity with other geophysical or solar disturbances.

RELATED GEOPHYSICAL PHENOMENA

Indeed, an important mission of this mobile station is to provide a continuous monitoring of the cosmic-ray intensity similar to that which is carried out by a far-flung "shore patrol" at various fixed stations distributed over the surface of the earth.

A neutron monitor responds to the progeny of the relatively low-energy cosmic rays upon which the effects of magnetic conditions in the vicinity of the earth are most pronounced. A decrease in cosmic-ray intensity is often associated with magnetic storms as a consequence of

FIG. 3. Lars Erikson of Uppsala University, observer on the first cruise, and the author.

either a deflection or deceleration of these particles. Furthermore, the monitored primaries are in the band of energy which, as has been directly observed on a number of occasions, can be produced on the sun. Rapid increases in the cosmic-ray intensity sometimes occur simultaneously with eruptions on the solar disk. These coincide with other geophysical phenomena, such as sudden ionospheric disturbances which result in a blackout of radio communications. The most recent of the five large increases recorded to date was observed on February 23, 1956 at stations all over the world. This event greatly exceeded all others in magnitude, the peak rising to 25 times the normal rate at some locations. Much useful information can be derived from comparisons of the data obtained at different points of impact on the earth.

The shipboard station provides coverage in a region where no other detector exists and it is of interest to compare any sudden changes

observed en route with those detected elsewhere, particularly during the forthcoming International Geophysical Year. For, during this period which coincides with sunspot maximum, the probability of large solar flares and other disturbances will be especially high.

AUTOMATIC FEATURES OF MONITOR

An observer from Uppsala University, under the direction of Dr. Arne E. Sandström, is accompanying the equipment during the first voyage, although the instrumentation has been designed in a manner such that the ship's radio operator will probably be prepared to assume charge of the observatory during subsequent voyages after indoctrination by the scientist who is now aboard. Except for certain routine inspections and maintenance procedures in accordance with a series of check-lists, the entire device functions automatically and is essentially self-checking. For example, in the event of an increase in the counting rate such that the meter deflects to full scale, the sensitivity of the counting-rate computer changes to provide for this contingency. Two steps, amounting to a factor of 10 each, are provided. Thus, an enhancement as large as 100 times normal, which exceeds the greatest increase ever observed previously, would be recorded without any loss of detail even in the absence of the observer.

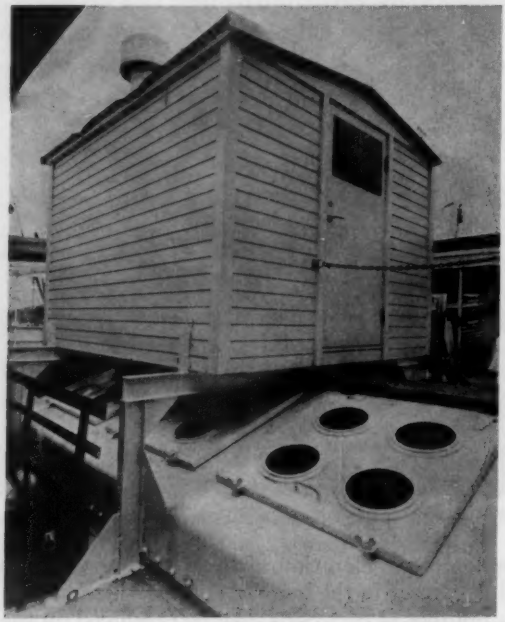

FIG. 4. Cosmic-ray observatory mounted on boat deck of Swedish merchant ship.

The neutron monitor (Fig. 3) is housed in a special pre-fabricated hut installed on the boat deck of the *M/S Lommaren* on a structure bridging the engine room skylight, as is shown in Fig. 4. The Transatlantic Company of Sweden has very generously made the ship available for these experiments, and the National Geographic Society is sponsoring the field operations. Funds from the U. S. National Committee for the International Geophysical Year and support from the Office of Naval Research have also aided this project.

FUTURE PROGRAM

Even before the present type of measurement was undertaken, there were experimental indications that the previously accepted geomagnetic coordinates based upon surface magnetic field measurements did not apply to the cosmic-ray particles. This has been confirmed and accentuated by the recent results from the monitor operated at sea, and the indications are that the simple eccentric dipole magnetic field does not adequately describe the outer magnetic field distribution with which the incoming cosmic-ray particles interact. Indeed, it has now been established that the earth is actually immersed in a highly-conducting interplanetary medium which, as a consequence of possible outer ring currents, has magnetic properties which affect the trajectories of all charged particles incident upon the earth. Whether or not these phenomena change with time, and the nature of the variations if they do occur, can be determined only by continuous observations of the type now under way in the long-term program which is contemplated.

Liquid-Injection System Increases Jet Engine Power.—A device to improve performance of the B47 bomber and enable it to take off from shorter runways was described to members of The American Society of Mechanical Engineers at their Annual Meeting. A liquid-injection system which introduces a mixture of alcohol and water into the airplane's jet engines thereby increasing power available for takeoff, is now installed on the majority of B47's according to M. K. Wolfson, manager of the General Electric Company's J47 engine project at Cincinnati.

Advantages claimed for the system include simplicity, reliability, precision of control, and economy. In addition the system permits the pilot to increase thrust before starting his takeoff. This contrasts with rocket assisted systems in which the rockets are not fired until the plane is traveling at high speed, making a misfire extremely hazardous.

Mr. Wolfson told the engineers that pilots favor use of the system, which increases thrust by 20 to 25 per cent. He predicted that the use of alcohol water systems would become increasingly frequent on B47's.[1]

Development of the injection system for the B47 engine began in 1948 when it became apparent that some method of augmenting thrust would have to be developed to enable heavier aircraft to take off from existing runways.

Plywood Used for Cold-Test Box.—A cold-test box of plywood construction is being used with satisfactory results in testing the equipment of a 15-ton mobile refrigeration plant at the Corps of Engineers' Research and Development Laboratories, Fort Belvoir, Va.

Although the box was designed to go into a large test cell, where it would be protected from the weather, it is being used as a separate outside test unit. Only a coating of white paint and a canopy of canvas protect it from the elements. The interior of the box is unpainted.

Engines up to 50 horse-power, that will fit into the box, are being tested for starting and operation at low temperatures.

Three-ply $\frac{1}{4}$-in. plywood was used in construction of both the exterior and interior of the box, which is of knock-down construction and which is mounted on a 6-in. concrete slab. Sections of the box are $8\frac{1}{2}$ in. thick, with the interior dimensions being 6 ft. 4 in. deep, 7 ft. $8\frac{1}{2}$ in. wide, and 8 ft. high. Aluminum foil sheets, 0.005 in. thick, are used for insulation with $\frac{3}{4}$-in. white pine separator strips used for spacing.

There is a full-opening door, equipped with hardware, and rubber strips are used for sealing. Cam-type clamps are used for pulling the sides of the box up tightly to make the seal.

Low temperature air is induced by a 2-ft. square duct, located at the top of the box, and is exhausted through a duct of similar size located at the bottom corner. Temperatures can be varied from + 100° F. to − 94° F.

The box was built by students in the engineering department of the University of Kentucky, Louisville, Kentucky.

THE BIOCHEMICAL RESEARCH FOUNDATION
ELLICE McDONALD, FOUNDER
WILLIAM G. BATT, DIRECTOR

2-DEOXY-D-GLUCOSE, A NEW SUBSTRATE FOR GLUCOSE OXIDASE (GLUCOSE AERODEHYDROGENASE)

BY

R. B. McCOMB, W. D. YUSHOK AND WILLIAM G. BATT

Glucose oxidase, recently designated glucose aerodehydrogenase (1), from the mold *Aspergillus niger* has been used in this laboratory as a specific reagent for the analysis of D-glucose in the presence of other hexoses. When attempts were made to estimate glucose in the presence of 2-deoxy-D-glucose, it was observed that glucose oxidase also catalyzes the oxidation of 2-deoxy-D-glucose.

In a comprehensive survey of the activity of 55 carbohydrates with glucose oxidase, Keilin and Hartree (2,3) found that all had less than 2 per cent of that of glucose. They concluded that substitution of the 1-, 2-, or 3-hydroxyl group of glucose virtually abolishes enzyme activity. However, 2-deoxy-D-glucose, which was not included in their survey, has been found to be an exception. It has been found to be oxidized at a rate which is approximately 12 per cent of that of glucose and much greater than that of other reported substrates of glucose oxidase.

MATERIALS AND METHODS

Glucose oxidase from *Aspergillus niger* was kindly supplied by Takamine Laboratories as a concentrated powder, Dee O, having an activity of about 1500 units per gram. This material was used without further purification as a filtered aqueous solution. Peroxidase (horseradish) was obtained from the Worthington Biochemical Corporation as a lyophilized powder with an activity of about 600 units per mg. *o*-Dianisidine, Eastman Kodak's T 509, was recrystallized once from ethanol before use. The sources of the other compounds were as follows: glucose, Baker's C.P. analyzed; mannose and fructose, Pfanstiehl Laboratories; glucono-1,4-lactone, California Foundation for Biochemical Research. 2-Deoxy-D-glucose was prepared in this laboratory by F. B. Cramer.

The method for measuring the glucose oxidase reaction was essentially that reported by Keston (4). The buffer has been changed to potassium phosphate, pH 5.9, and much smaller amounts of glucose oxidase have been used. The method is based on the oxidation of glucose by glucose oxidase to form gluconic acid and hydrogen peroxide. The latter produces an amber color with *o*-dianisidine in the presence of peroxidase.

The reaction mixture was prepared by addition of the required amounts of peroxidase and *o*-dianisidine (dissolved in ethanol) to the

phosphate buffer, followed by dilution with water to the desired final concentration. Glucose oxidase, dissolved in the same buffer, was added to start the reaction.

The reaction was followed by observing the development of the colored oxidation product of *o*-dianisidine, by means of a Klett-Summerson photoelectric colorimeter equipped with a No. 54 filter. The reaction mixtures in the colorimeter tubes were allowed to stand at room temperature (25° C.) between readings. The relation of substrate oxidized to color produced was established by measuring the color which developed when a small amount of glucose (0.2 micromole) was completely utilized.

RESULTS AND DISCUSSION

The relative reaction rates of four representative substrates are shown in Table I. Because of the great differences in glucose oxidase

TABLE I.—*Relative Reaction Rates of Some Hexoses with Glucose Oxidase.*

Hexose	Relative Reaction Rate
D-Glucose	100
2-Deoxy-D-glucose	11.9
D-Mannose	0.94
D-Fructose	0.02

Composition of reaction media: *o*-dianisidine (0.0050%); peroxidase (0.002%); hexoses (0.05 M); potassium phosphate, pH 5.9 (0.1 M); glucose oxidase (0.005 to 0.10%). Total volume, 2.0 ml. Temp., 25° C. Gas phase, air. Rates calculated from the initial portion of the reaction where rates are linear.

activity with various substrates, 2-deoxy-D-glucose was compared with glucose at one level of enzyme concentration and it was compared with fructose and mannose at a higher level of enzyme concentration. All rates were then calculated on the basis of glucose as 100.

This modified Keston method of measuring glucose oxidase activity has advantages over the manometric method employed by Keilin and Hartree in that measurements are faster and more sensitive. With this greater sensitivity, more dilute enzyme solutions are used and difficulties due to inadequate oxygen supply and inhibition by natural inhibitors are largely eliminated.

Several attempts were made to measure manometrically the rates of various substrates. The procedure was essentially that of Keilin and Hartree (2) but no extra catalase was added. In all cases the observed rates were much lower and the differences less pronounced than those obtained with the Keston procedure. The order of activity, however, was still the same.

Since the possibility existed that 2-deoxy-D-glucose and glucose were being oxidized by separate enzymes, an attempt was made to demonstrate competitive inhibition between these two hexoses. Competition between these substrates would indicate that the same enzyme was

acting on both. From the results which are shown in Table II, competition is apparent, since the reaction rate of the combination of glucose and 2-deoxy-D-glucose is considerably less than that of glucose alone. No attempt was made to calculate the relative affinities of these sugars for glucose oxidase because of the difficulty in separating the activities contributed by each.

The products of the 2-deoxy-D-glucose reaction have not been positively identified but appear to be 2-deoxy-D-gluconic acid and its 1,5- or 1,4-lactone. A chromatographic analysis of the reactants and products of glucose and 2-deoxy-D-glucose reactions is shown in Fig. 1. A non-

TABLE II.—*Competition of 2-Deoxy-D-glucose and Glucose for Glucose Oxidase.*

Substrate	Total Hexose Used micromoles/5 min.	Relative Reaction Rate
0.04 M Glucose	0.288	100
0.04 M Glucose 0.16 M 2-Deoxy-D-glucose	0.125	43
0.16 M 2-Deoxy-D-glucose	0.054	19

Composition of reaction media: *o*-dianisidine (0.004%); peroxidase (0.0016%); glucose oxidase (0.00125%); potassium phosphate, pH 5.9 (0.1 M). Total volume, 2.5 ml. Temp., 25° C. Gas phase, air. Rates calculated from time required for change in optical density corresponding to 150 divisions on Klett-Summerson colorimeter.

enzymatic preparation of 2-deoxy-D-gluconic acid prepared by bromine oxidation of 2-deoxy-D-glucose is included for comparison. This oxidized product was later compared chromatographically with a pure sample of 2-deoxy-D-gluconic acid (prepared in this laboratory by F. B. Cramer). The oxidized products of 2-deoxy-D-glucose were shown to be chromatographically identical.

The enzymatic reaction mixtures from which these samples were taken were 0.0067 M in glucose and 0.033 M in 2-deoxy-D-glucose respectively. The glucose oxidase concentration was 0.25 per cent and the medium was 0.1 M with respect to phosphate. The reaction was run at 30° C. in air and at pH 5.9. Samples were withdrawn and chromatographed at the start of the reaction and after 300 min.

Analysis of the chromatogram indicates that glucose has been completely utilized and its reaction product, presumably gluconic acid, appears in G_f just above the spot left by inorganic phosphate at the origin. The 2-deoxy-D-glucose, however, besides giving two new spots due to reaction products (2 DG_f), still has some unreacted starting material. Since the positions of these products coincide with those made by the bromine oxidation products, they are probably 2-deoxy-D-gluconic acid and 2-deoxy-D-glucono-1,5- (or 1,4-) lactone.

A small amount of impurity migrating at the same speed as glucose is present in the 2-deoxy-D-glucose. Isolation and identification of this component by column chromatography and quantitative sugar analysis

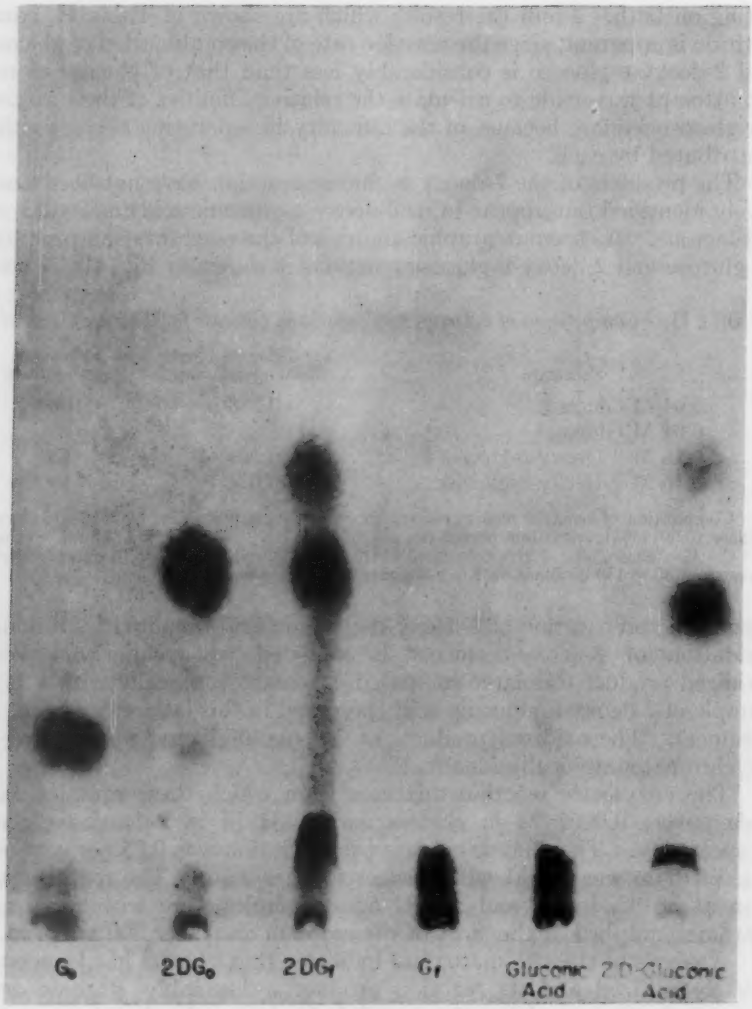

FIG. 1. Chromatogram of the products and reactants of the glucose oxidase reaction.

Paper: Whatman No. 1. Ascending technique. Solvent: butanol/pyridine/benzene/water, (5). Time: 16 hr. at room temp. Chromatogram developed with 5 per cent ammoniacal silver nitrate.
G_0: initial glucose, R_f 0.24.
$2DG_0$: initial 2-deoxy-D-glucose, R_f 0.46 (impurity, R_f 0.23).
$2DG_f$: final 2-deoxy-D-glucose, R_f 0.12 and 0.59, unreacted 2-deoxy-D-glucose, R_f 0.46.
G_f: final glucose, R_f 0.05.
Gluconic acid: 0.05 M glucono-1,4-lactone, R_f 0.05.
2 D-Gluconic acid: Bromine oxidized 2-deoxy-D-glucose, R_f 0.10 and 0.58, unreacted 2-deoxy-D-glucose, R_f 0.41.

indicates that this impurity is probably glucose, but that the amount is less than 1.0 per cent.

It is important to establish that this glucose impurity does not give a false indication of activity as was shown by Keilin and Hartree to be the case for galactose contaminated with glucose. That 2-deoxy-D-glucose is truly a moderately strong substrate for glucose oxidase, and that the activity demonstrated by it is not just due to glucose impurity, is shown by the following:

1. Reaction rates were found to be the same when a small amount of chromatographically pure 2-deoxy-D-glucose (prepared by F. E. Reinhart in this laboratory) was compared with the sample containing the impurity.

2. A strong affinity of glucose oxidase for 2-deoxy-D-glucose was demonstrated by competition experiments with glucose.

3. Rates determined by a sugar disappearance procedure, in which the quinaldine method, developed specifically for 2-deoxy-D-glucose by Cramer (6), was employed, showed the same order of magnitude as those obtained by other less specific methods.

4. The initial rate of the 2-deoxy-D-glucose reaction was maintained over prolonged periods of incubation.

SUMMARY

2-Deoxy-D-glucose has been shown to be a substrate for glucose oxidase. The activity of 2-deoxy-D-glucose as a substrate for this enzyme is intermediate between that of highly active glucose and that of the other known substrates, all of which are nearly inactive.

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BOOK REVIEWS

AUTOMATA STUDIES, edited by C. E. Shannon and J. McCarthy. 285 pages, 7 × 10 in. Princeton, Princeton University Press, 1956. Price, $4.00.

This fascinating but highly uneven book offers both an excellent introduction to a wide range of interesting and important work and in many instances a philosophical immature viewpoint which obscures the more fundamental aspects of the subject.

Probably, we are too close to it to appreciate the full impact of the introduction of "logical" automata in both scientific and technical fields. In technical matters at least, it is readily admitted that a situation is effectively analyzed when an automaton has been developed which produces a symbolic analogue describing the situation.

The possibilities of these symbolic representations are extradordinary. From nuclear phenomena which occur in a fraction of a microsecond to cosmic phenomena lasting billions of years, the range of symbolic representation corresponds to a tremendous expansion of human experience. Most of the striking technical achievements which are new in the present era, are possible only because of the use of analytic automata.

The fundamental assumption is that there are patterns in phenomena generated by certain basic relations which are far simpler than the total effect. An automaton can be constructed which has an analogue in a proper symbolism of the basic relations and it will reproduce the phenomena. If one has good agreement with observation, then the phenomena are understood.

Furthermore, we can ourselves introduce certain basic relations into the situation so that the final pattern is suitable for our purposes. These are "control elements" which have much the same nature as the "logical" automata used for analysis and normally their design, which is a matter of great practical importance, is based on the use of logical automata.

The key, of course, is the matter of effective representation. One broad important class of symbolic representations of basic relations is given by the mathematical description of physical phenomena. But mathematical solutions of these basic relations are confined generally to nearly trivial cases. Logical automata can, however, obtain developments far beyond these mathematical relations. Furthermore, the class of possible representations seems to be broader than those which have a purely mathematical expression.

The automaton is not confined to a finite number of possibilities, a result which is evident from Türing's machine. One can have a storage medium of indefinite length so that the automaton is not confined to a finite number of possibilities.

It is clear, then, that there is a sense in which the automaton "thinks out" the situation which is being considered. There certainly seem to be cases in which transistors and their circuitry can construct this kind of "thinking out" relationship better than our own weary little brain cells. Furthermore, we can establish patterns for discovering basic relations, especially when we have had a considerable experience relative to them. These patterns can themselves be analyzed and the fundamental relations represented by automata.

But in all this, there are certain limitations, certain questions of categories which cannot be settled simply by fiat. Experience indicates that, on the whole, an automaton will function only within a range of experience for which it has been effectively designed. An automaton whose purpose is to extract the basic patterns from a range of experience will do this only within a larger framework which has been properly analyzed in advance. There is always a category of experience to which it applies and it is limited to it. Notice that if our acceptance of the basic patterns is to be justified, then we must have proof which corresponds to an analysis of the over-all situation. It seems to the reviewer that this point is of basic importance for the develop-

ment of the full power of this type of analysis, and such a development cannot ignore the question of categories.

Many of the memoirs in this book are technically excellent, but others represent what seems to the reviewer naive discussion of the automata in which the problem of category is deliberately ignored. Much of the work is concerned with the two extraordinary examples of the use of automata models in analysis. One is that of Pitts and McCulloch in which neuron nets are represented by elementary logical elements. The other example is the representation of formal logics by a Türing machine. The book has an interesting article by Kleeney containing a carefully developed version of the Pitts and McCulloch theory. There are a number of valuable papers on the Türing machine and there is an interesting discussion by von Neumann of the general problem of error correction.

However, the reviewer could see little value in the paper by Culbertson and the more pretentious paper of Ashby. The paper of Ashby in particular, has received considerable attention, but the reviewer cannot agree with its simplification of intelligence into a mere matter of selection. And that even if this simplification was accepted, the basic theorem given by Ashby has no real significance for the solution of problems. To the reviewer it seems as if the paper of MacKay which immediately follows, is basically more useful even though the category question has not been squarely faced in the MacKay paper either.

However, in conclusion, one should emphasize that this book is extremely interesting. No great technical training is needed to understand the work in general and perhaps in it there sounds the marching cadence of a new revolution. F. J. MURRAY

MATERIALS OF ENGINEERING, by Carl A. Keyser. 502 pages, illustrations, 5½ × 8½ in. New York, Prentice-Hall, Inc., 1956. Price, $8.00.

In all fields of engineering design, the practicing engineer is called upon to reduce cost, weight, and size, and at the same time improve performance. In fulfilling these requirements, a knowledge of the properties, testing and selection of engineering materials is essential. Modern materials technology has made available to the engineer an ever increasing number of materials to fit the various requirements presented by the complex devices he must design and build. At some time during his engineering education, the engineering student should be made aware of the many materials which are available. This book which is primarily designed for use as a text, presents a well-organized introduction to this subject. However, although elementary, it is not limited to use only as a text book. It is an excellent guide to the practicing engineer.

Each chapter contains a well-organized summary and bibliography. The book is broken up into three parts, one on metallic materials, another on inorganic non-metallic materials and the third on organic materials. Considerable space in this volume is devoted to the methods of testing engineering materials. Included also is a discussion of the mechanism of failure. The processing of materials from the raw state to the finished product including the effects of various processing methods on the final properties of the material is discussed.

The first and major part of the book is devoted to metallic materials. The author discusses the fundamentals of metal structure, testing of metals under static and dynamic loads, high temperature testing, corrosion and corrosion testing, and the various methods of metal production. The section is concluded with a discussion of the methods of fabrication, and their effects on the properties. Part II is a discussion of inorganic non-metallic materials, and the author here discusses minerals, inorganic cementing materials and concrete. Following this is the third section on organic materials in which plastics, rubber, organic coating and wood are covered.

The author, a Professor of Metallurgy at the University of Massachusetts, has done an excellent job in organizing the material and discussing it in a manner which makes it interesting to the non-metallurgist. The book is well-referenced and well-organized with a comprehensive index. Where this volume is lacking in the necessary detail due to its wide scope, adequate references are supplied to permit the reader to continue to pursue the particular field of information in

which he is interested. The book is well-illustrated with graphs, photographs and tables. This book, although it is designed specifically for the student, would provide a good reference on the book shelf of any practicing engineer.

A. M. LOEB

RADIATION DOSIMETRY, edited by G. J. Hine and G. L. Brownell. 932 pages, illustrations, 6 × 9 in. New York, Academic Press Inc., 1956. Price, $22.00.

This book is a composite of the efforts of many distinguished contributors. The discussions of the many topics treated are quite thorough. The contents are divided into three large sections entitled respectively "Fundamental Principles of Dosimetry," "Radiation Detectors and their Calibration," and "Radiation Fields and their Dosimetry." Each section contains numerous chapters dealing with various aspects of the particular subject in question. The material contained in the book covers a much broader field than is indicated by the title. Many clinical applications are discussed including therapeutic aspects of X-rays and internal uses of radioisotopes.

Throughout the text, the ultimate emphasis is upon the biological aspects. Calculations applicable to tissue, for example, are carried out as often as possible. The effects considered deal with the role of X-rays, γ-rays, β-rays, heavy charged particles, and neutrons, slow and fast. This book contains many useful curves dealing with such topics as gamma-ray absorption coefficients, ranges of charged particles in matter, depth-dose curves, etc.

It should be pointed out that this book makes use of mathematics extensively in derivation of formulae pertinent to all aspects of the subject of dosimetry and related matters. Although this practice might be looked upon with misgivings by medical men unfamiliar with mathematics, the quantitative approach is of great importance to radiologists and radiation physicists working in medical schools and hospitals. The mathematical techniques illustrated are those with which radiologists in particular must become familiar if they are to do research and make innovations and advances in their field.

C. E. MANDEVILLE

NONPARAMETRIC STATISTICS FOR THE BEHAVIORAL SCIENCES, by Sidney Siegel. 312 pages, 6 × 9 in. New York, McGraw-Hill Book Co., Inc., 1956. Price, $6.50.

Although various nonparametric statistical tests of hypothesis have been advanced in recent years, their rather infrequent use has probably been due more to their inaccessibility than to any other valid objection In an attempt to eliminate this condition the author, Sidney Siegel, has collected most of the nonparametric statistical techniques known and has presented them in usable form and in terms familiar to the behavioral scientist. While presenting the case of the behavioral scientist he has served every applied statistician as well.

No attempt has been made to derive or even to justify mathematically any of the techniques. The emphasis is on how and when each technique is used. Consequently, a knowledge of mathematics no more demanding than elementary algebra is required to appreciate the content of this book.

The first three chapters are devoted to the philosophy of statistical inference and the explanation of concepts fundamental to hypothesis testing. In this section the author describes six ingredients which are found in every statistical test, parametric and nonparametric. These are (1) the null hypothesis, (2) the statistical test, (3) the level of significance, (4) the sampling distribution, (5) the region of rejection, and (6) the decision. In every example throughout the remaining six chapters, these properties are displayed to show, in the author's words, "that identical logic underlies each of the many statistical techniques." In chapter three an interesting discussion of measurement is found. Four general scales of measure are presented together with their formal properties and admissible operations; these are (1) Nominal scale, (2) Ordinal scale, (3) Interval scale, and (4) Ratio scale. Parametric statistics are confined to data in the latter two scales, while nonparametric statistics are available for data in any of the four. This fact alone should make nonparametric statistics especially appealing to the social scientist, whose test data are very often of the classificatory and ranking variety.

Some of the other advantages of nonparametric statistical tests set forth are:

(1) Probabilities are exact regardless of the shape of the population from which the sample is drawn, (2) there are nonparametric tests for handling data made up of observations from several different populations, (3) the power-efficiency of a nonparametric test can be improved by simply increasing the sample size, and without making any unwarranted assumptions about the data.

The tests, which are many, are presented in an easy-to-digest form. Among these tests are the binomial test, chi-square one, two, and k sample tests, Kolmogorov-Smirnov one and two sample tests, McNemar test, Sign test, Mann-Whitney U-test, Cochran Q-test, Kruskal-Wallis one way analysis of variance, and some nonparametric measures of correlation due to Spearman and Kendall.

An extensive bibliography, to which reference is frequently made, is listed at the end of the text material. A complete set of tables necessary for the various tests is also included.

The reviewer considers this book a valuable asset to the library of any scientist concerned with statistical inference.

LAURENCE C. MCGINN

A SPACE TRAVELER'S GUIDE TO MARS, by I. M. Levitt. 175 pages, plates, 5¼ × 8¼ in. New York, Henry Holt and Company, Inc., 1956. Price, $3.50.

We live on "the best of all possible worlds" in the opinion of Voltaire's Candide but interest in the next best world is currently at its highest level. The next best world is obviously the planet Mars and viewed in its natural rosy hue across 36,000,000 miles there is an enchantment in this pristine land that beckons the modern adventurer—both the juvenile space "buff" and the missile engineer who spends your tax money. Here in the sky is a vast expanse of sun-lit land over the title to which not an ounce of human blood has yet been shed.

There is one scientific writer who has, better than anyone else, kept the "Rocket to Mars" movement in correct perspective. He is Dr. I. M. Levitt, the busy director of the Fels Planetarium of The Franklin Institute, and now his *A Space Traveler's Guide to Mars* puts between handsome hard covers the soundest and yet the most exciting story to be had about "The Nearest Land."

A few of Dr. Levitt's more solemn colleagues feel the title is a bit florid for a work that emphasizes the rigors of interplanetary travel, but the publisher had his way and the fainter-hearted suggestions were discarded. This is a true space-marker in Martian literature. The first great writer was the astronomer Schiaparelli, discoverer of the canals on Mars in 1877. The "cause" was then taken up by the Frenchman Flammarion and brought to a controversial climax by the eloquent Percival Lowell who died in 1916.

Lowell stirred the whole world with his theories about "Mars as the Abode of Life" and at the same time so antagonized the professional astronomers that all but Antoniadi stoutly refused to look at the little planet for a whole generation. Then came the change. Dr. Gerard P. Kuiper headed a movement to re-examine the planets with modern techniques. The activities of this school coincided with the rise of rocket science and today the major theoretical obstacles to the direct exploration of Mars have been removed.

It is the reader's good fortune that Dr. Levitt has followed recent rapid advances on both the astronomical and the guided missile fronts. The integration of the best scientific opinion in these fields gives extra meaning to such challenging chapters as "Men Against Mars" and "The Nearest Land." Not only is "The Face of Mars" a convincing report on things as explorers will find them, but "In the Beginning" relates the evolution of the planet down to our time.

One of the most significant contributions to the subject of life on other worlds is contained in the chapter "Life on Mars." While in the past there have been heated debates as to the possibility of life on Mars, now for the first time a scientist tries to describe the life we might find on Mars when space travel becomes a reality.

Most astronomers agree that vegetable life exists on Mars. That is the only plausible explanation for the seasonal changes which are found telescopically. But, reasons Dr. Levitt, if vegetable life exists there, then most certainly a form of animal life must be found which can oxidize the vegetable life to replenish the supply of elements necessary to keep the vegetation flourishing. To complete the cycle, a form of animal life is postulated which can exist on the planet Mars and take part in the completion of the life cycle.

In the past it has been easy to dream up all forms of exotic life which could inhabit a planet. But here, using hard fact, Dr. Levitt has postulated a form of life which could be found on Mars in the light of our terrestrial experience. The introduction of a rodent form of life with a daily and hibernating cycle and with a metabolic system which breaks up the water locked in vegetation to furnish the oxygen necessary for the metabolic processes are intriguing and add a milestone to our knowledge of the planet. Today this is a matter of speculation, but if we reach Mars at the turn of the century, as Dr. Levitt indicates in his time-scale for the exploration of space, then the validity of these theories will be explored.

There is a curious feeling that in the writing of this book Dr. Levitt was not too concerned with the problem of Mars, but rather with the entire subject of Life on Other Worlds. In the appendix there is a skillful bit of exposition on the origin of life on the earth. This is a subject which has been debated and explored since man's earliest day. To this story there is one significant contribution and that is the method by which the primitive cell was fashioned. The invoking of the formation of formaldehyde in the atmosphere and the building of the permeable plastic sheath of this plastic to prison the nucleus is an ingenious attempt to resolve the problems inherent in the cell formation.

This book of 175 pages and well-chosen illustrations is such a happy combination of past and promise that it deserves to rank with the best science non-fiction of the year. Dr. Levitt proves that Mars, like New York, is a great place to visit, but you wouldn't want your worst enemy to live there.

J. W. STREETER

SCIENCE AND ECONOMIC DEVELOPMENT, by Richard L. Meier. 266 pages, illustrations, 6 × 9 in. New York, John Wiley & Sons, Inc. and the Technology Press; London, Chapman & Hall, Ltd.; 1956. Price, $6.00.

Demographic experts place the world population at about 6 billion within the next century. Today many scientists are alarmed at this explosive population growth and some highly articulate ones have expolored this problem and have committed to books their findings. For the most part, scientists who have explored this have been concerned with single facets of the problem.

Actually the problem of the further development of the earth is one of many facets. They are not autonomous and whoever writes of them must recognize the intimate interrelation. While on the whole this has been neglected, today we find one scientist who has placed the various parts of the problem in their proper perspective.

In *Science and Economic Development*, Dr. Richard L. Meier of the University of Chicago, has focussed his attention on one of the most acute problems which faces civilization today—the problem of increasing population. In a skillfully written and well documented book of four sections, he portrays the world of the future and the awesome problems to be faced at that time.

The first section deals with some basic problems, such as population growth, the needs of the individual in terms of food, power, minerals and clothes. In the succeeding sections he examines these problems in detail to show where we are, the state of our technological progress, and where we go. He paints a graphic picture of technology of the future.

His cogent analysis of the food question today and of the future is a scholarly work of great merit. The reader is shown the avenues along which may lie the answer to our food problems of the future. The protein problem, which at the moment is of considerable concern in some parts of the world and is destined to become more acute in the future to the entire world, is explored. The author paints a grim picture of this for certainly in time a steak will be a thing of the past. Most of the proteins will come from the soil or the water.

The question of fuels is thoroughly discussed but in this chapter the reviewer takes issue with the author. The world power picture under severe population stress is indeed grim. But the author has not extrapolated in this field as he has in others. He shows that it is difficult to arrive at conclusive figures on atomic (nuclear) energy which is a recognized problem today and he strongly stresses the use of solar power in the future. With this the reviewer agrees but the author should also have added a section on the possibility of energy from the fusion process. If this form of energy release is achieved,

and this reviewer believes it is simply a question of directives and monies to consummate, then all energy problems of the future will become academic. There will be sufficient energy for all purposes for everybody in the future.

The question of minerals for future development and for the use of increased population is an easy one to answer. Present developments indicate that it will be increasingly difficult to obtain these raw materials and as time goes on, they will become scarcer. Perhaps our technology will find man-made substitutes for some of the strategic materials. But there will be some which will always be in short supply.

Dr. Meier has compounded a stimulating book and deserves the fullest credit for pioneering in a field so vital to the peoples of this earth. He has indicated the paths which science must take to preserve the population of this earth.

I. M. LEVITT

CHROMIUM. VOLUME 2. METALLURGY OF CHROMIUM AND ITS ALLOYS, edited by Marvin J. Udy. ACS Monograph 132. 402 pages, diagrams, 6 × 9 in. New York, Reinhold Publishing Corp., 1956. Price, $11.00.

Volume I of this two-volume monograph covered the chemistry of chromium and its compounds. This volume deals with the metallurgy of the metal and its alloys. It is divided into three sections containing a total of nineteen chapters written by twenty-one authors.

Section I covers the extraction of chromium from its ores, the production of ferrochromium, electrowinning, electroplating and other methods for the deposition of chromium.

Section II summarizes the physical properties of chromium and many of its alloys. The binary phase diagrams are given. The curvatures of the phase lines are not reproduced accurately from the references as given but are generally smoothed out considerably. The chromium-carbon system is mislabeled in one field that is marked CR_7C_3 + liquid instead of Cr_3C_2 + liquid. In some cases the author does not present the latest information available. For instance, the CrMn, CrW, and CrZr systems have been published more recently (1,2,3,4). There are rather serious disagreements among the various investigators and in such cases it would be helpful if both versions of the phase diagrams were shown or at least referenced. The CrTa diagram was omitted (5). In spite of these criticisms, this collection of binary systems of chromium alloys is the most complete published to date.

A very short chapter is devoted to the intriguing problem of ductile chromium. Unfortunately no quantitative mechanical properties were given.

The remainder of Section II is devoted to chromium in austenitic and ferritic steels, cast iron and high temperature alloys, nickel-base, cobalt-base and titanium-base alloys, aluminum alloys, copper alloys, and electrical-resistance alloys. Most of these chapters are well written and fairly detailed.

Section III deals with the use of chromium in refractories and gives a considerable amount of practical information on the subject. There is a subject index.

R. L. SMITH

(1) W. B. PEARSON AND W. HUME-ROTHERY, *J. Inst. Met.*, Vol. 81, p. 311 (1952–53).
(2) J. W. CHRISTIAN AND W. HUME-ROTHERY, *Nature*, London, Vol. 167, p. 110 (1951).
(3) H. T. GREENAWAY, *J. Inst. Met.*, Vol. 80, p. 589 (1951–52).
(4) R. F. DOMAGALA, D. J. MCPHERSON AND M. HANSEN, *Trans. AIME*, Vol. 197, p. 279 (1953).
(5) O. KUBASCHEWSKI AND H. SPEIDAL, *J. Inst. Met.*, Vol. 75, p. 417 (1949).

PHOTOCONDUCTIVITY CONFERENCE, edited by R. G. Breckenridge, B. R. Russell and E. E. Hahn. 652 pages, diagrams, 6 × 9 in. New York, John Wiley & Sons, Inc., 1956. Price, $13.50.

This book derives its distinction and utility from the nature and content of the conference on photoconductivity held at Atlantic City in 1954. The purpose of the conference was to "advance the science of photoconductivity through plenary discussion among the leading workers in the field." This book, a record of the conference, is not therefore burdened with an account of the minutiae of special investigations that have been made in the field, as is often found in other "reports of conferences," but rather covers the basic phases of the subject in sufficient detail to serve as a comprehensive introduction as well as a treatise for advanced workers.

The section headings are as follows: I. Phenomenalogical Theory of Photoconductivity; II. Photon Absorption Process; III.

Electron Process; IV. Photoconducting Materials; and V. Current Topics.

The choice of this order is very fortunate, especially that of the first article, Performance of Photoconductors, in Section I. Here, by introducing such concepts as life time, transit time, recombination rates and noise spectrum as well as providing a quantitative estimate of the magnitude of the parameters introduced, the author sets the stage for the following articles by giving the reader a physical appreciation of the processes involved.

Section II follows logically by describing the interaction of the incident photon with the lattice. The articles included are: Theoretical ideas pertaining to traps or centers, The influence of lattice vibrations on electronic transitions in solids, Indirect transitions from the valence to the conduction bands, Absorption near the edge in insulators, Infrared absorption and energy-band structure of germanium and silicon, and Note on the statistical mechanics of semiconductor crystals with electron-vibration coupling.

Section III continues the history of the photon by describing the fate of the charge carriers produced by the incident photon. Included articles are: Electron processes in photoconductors, The range of charge carriers in photoconductors, The role of chemisorption in surface trapping, Interfacial photoeffects in germanium at room temperature, The photoelectromagnetic effect, and The trapping of minority carriers in silicon.

In Section IV the photo properties of Germanium, Silicon, and the various intermetallic compounds such as InSb, GaSb, Mg_2Sn, as well as PbS and ZnO, are discussed and analyzed. Perhaps it would have been desirable to devote more space to detailed experimental techniques such as the fabrication of the crystals, measurement of life times, etc.; however there are included many tabulations of the physical properties of these materials for easy reference.

In the last section there are collected a few specialized topics that are not general enough to be conveniently classified in the above sections. The majority of these articles deal with intermetallic crystals and films.

Each article is followed by a resume, where possible, by extensive references, and a transcription of the pertinent discussion. This last item is well worth the additional effort it must have caused, and is a good example of the thoroughness with which these papers have been collected and compiled. There is a subject and author index for the entire volume.

This book could well serve as a model for future "reports" of a similar nature.

RAYDONG SUN

SODIUM, ITS MANUFACTURE, PROPERTIES AND USES, by Marshall Sittig. ACS Monograph No. 133. 416 pages, diagrams, 6 × 9 in. New York, Reinhold Publishing Corp., 1956. Price, $12.50.

This ACS Monograph continues the high standards of scholarship and bibliogony set by the Board of Editors. Generally it fulfills the purpose stated in the preface, ". . . we have attempted to cover all that is currently important in the manufacture, handling and use of sodium, and have included a critical resumé of the physical and thermodynamic properties of sodium (chapter 9). Aside from this, the treatment in this volume is that of a comprehensive literature summary. We have made every effort to include the most recent and most important references on any given topic. The textual treatment accorded the various topics has been purposely kept brief to keep this volume to a minimum size." Sodium compounds derived from sodium are included in the scope.

The first chapter, Introduction, gives a brief, readable review of the discovery of sodium and the development of manufacturing processes which permit the sale of over 140,000 tons annually at about 16 cents a pound, and points out the interest of the metallurgical, pharmaceutical, plastics and petroleum industries. There is a useful table comparing the physical properties of the alkali metals. The second chapter on the "Manufacture of Metallic Sodium" varies from readable to "comprehensive literature summary." The electrolytic cells and their operation are carefully reviewed.

The various sodium amalgams take up much of the chapter 3, Solubility and Alloy Formation, illustrated with some 19 phase diagrams with emphasis on the lead-sodium and sodium-potassium ("Nack") alloys. Ammonia, organic liquids and molten salts are other solvents.

Anyone using metallic sodium should feel

obliged to read chapter 4, Handling Metallic Sodium. Perhaps naturally, it is the most readable since it is not primarily a literature summary although plenty of references are included.

Chapter 5, Uses of Metallic Sodium, is usually kept to brief descriptive paragraphs based in part on the physical property employed and in part on the application, nuclear power plants and hardening metals for instance.

The next two chapters on "The Inorganic Reactions of Sodium" and "The Use of Sodium in Organic Reactions" are long and primarily summaries of references with an occasional lapse into description of more important processes.

A brief chapter 8, The Analytical Chemistry of Sodium, again primarily a literature summary, closes the presentation by Sittig.

Much space could have been saved and greater interest gained by naming only the first author of each reference or series of references in the text. Furthermore the practice of placing references at the end of the chapter has some value where the author is trying to present a readable story, but for a literature survey there seems to be no justification.

Chapter 9, Physical and Thermodynamic Properties of Sodium, by G. W. Thomson and E. Garelis is an outstanding addition to the literature—a complete and "new evaluation of the most important properties of sodium. . . . It is hoped that this critical survey will be of value to all users of sodium and that it will stimulate further research. . . ." Some data on viscosity and vapor pressure are here published for the first time.

The proofreading and editing left surprisingly few typographical errors in the text. While no attempt was made to check references, it happened that the one, Schaidhauf, which was checked because of personal interest turned out to be misspelled both in the text, page 198, Schaidhaut, and index and in the citations, Schraidhout, page 257. Further sampling of text and references showed excellent agreement. On page 183 Harris actually refers to Harris and to Hillix, while on page 328, Samieski should be Sómieski as in the references and not Smoieski as the index has it.

Although there are undoubtedly other errors and the citation of Schaidhauf (above) is certainly not the best recent reference to the stabilization of sodium peroxide, we can have nothing but praise and appreciation for the author and his associates whose long hours of labor and nervous tension have made possible this very useful addition to chemical literature.

J. H. WILLS

MAN OF HIGH FIDELITY: EDWIN HOWARD ARMSTRONG, by Lawrence Lessing. 320 pages, illustrations, $5\frac{1}{2} \times 8\frac{1}{2}$ in. Philadelphia, J. B. Lippincott Co., 1956. Price, $5.00.

Edward Howard Armstrong, a Franklin medallist, was a difficult man to assess on a somewhat casual acquaintance, for he had some peculiarities of personality. The turbulence of his life has clouded his status as an inventor, but there can be no doubt upon the brilliance of his mind. His three basic contributions to radio: the regenerative or feed back circuit, the superheterodyne circuit, and frequency modulation were landmarks in the history of the science. A fourth invention, superregeneration, may yet have a bright future. With these achievements to his credit, it may be thought he was entitled to honor and repose. This was far from his reward. Honors came to him without stint, but he was dogged by ill-luck through a life that ended in tragedy.

Probably no great inventor of modern times is so little known or so misunderstood. A comprehensive account of his life has not been available until Lawrence Lessing attempted it. He had the advantage of long acquaintance with Armstrong, and has had access to all papers and people necessary to make a complete biography. If he is partisan in viewpoint that may be forgiven, for when an individual stands alone against apparently overwhelming odds, he needs a partisan to understand and to interpret the uncompromising resolution and the motives behind his public attitude.

Armstrong was still an obscure undergraduate at Columbia when he began to develop the regenerative principle, a subtle conception of the minute currents of the vacuum tube. Up to this time De Forest's "Audion" tube had been only another detector, but now its value was apparent as an amplifier, and

transoceanic and long distance wireless communications could develop. Six years later he conceived the superheterodyne which, although not as fundamentally important, became the heart of the modern radio. This was the prelude to a nightmarish existence in which the industry began to resemble a hill of demented ants, with agreements, suits, and countersuits over the 2000 patents that had grown up like weeds about the wireless art.

Armstrong became involved in years of litigation, either in defense of his own patents or in attacking the patents of others. Mr. Lessing has waded patiently through the mass of testimony in these cases in order to present an accurate picture of the embattled Armstrong, and he illuminates the proceedings with incisive and sensitive comments, presumably based upon Armstrong's private papers. Throughout the whole bitter controversy the author is conscious of his subject's character, his pride, stubbornness, and secrecy.

By his invention of frequency modulation, Armstrong showed himself to be a more precise mathematical thinker in terms of the physical concepts underlying mathematics than anyone had suspected, but he lacked the ability to see or to elaborate the mathematical consequences of his ideas. He was occupied from 1928 to 1933 in getting FM into working order. This was a task of extraordinary complexity which only a man of his unique combination of qualities could have accomplished. Then came the inertia of industry, which failed completely to appreciate the value of his invention or, appreciating it, would not take advantage of it. The situation is described at length by the author with sympathy and understanding.

Mr. Lessing had set himself a difficult task, for he had to deal with a difficult man. Armstrong was almost monolithic in his inflexibility; he did not suffer fools or injustices gladly, as the author notes. Life would have been much easier for him had he been more adaptable, but he refused to compromise. The author has handled his materials with skill and has the ability to invest with interest a narrative that could easily have been tedious. He has treated his subject so deftly that no reader will lay down the volume without feeling that a great man was pursued to a tragic end that was both undeserved and unnecessary. T. COULSON

VACUUM-TUBE CIRCUITS AND TRANSISTORS, by L. B. Arguimbau and R. B. Adler. Second edition, 646 pages, diagrams, 6 × 9 in. New York, John Wiley & Sons, Inc., 1956. Price, $10.25.

Since it first appeared in 1948, Arguimbau's *Vacuum Tube Circuits* has achieved a considerable recognition as an excellent text in its field. The material in that book has been revised and brought up to date in this new edition, with no major changes in the material on vacuum tube circuits. An apparent condensation, suggested by the fewer number of pages in most chapters of the new edition is illusory; the new book is of larger page dimensions, so that there are more words per page. There have been some minor rearrangements; noise has been accorded a chapter of its own; the chapter on television has been expanded by the inclusion of material on color television; the chapter on microwaves has been modified and retitled "Transit Time." Problems have been revised, rearranged and supplemented; figures have been redrawn with improved clarity; and references to recent literature have been added.

All these revisions are likely to increase the value and reputation of the book, but they are just the sort of revisions we would have expected. The noteworthy change is the addition of material on transistors, by R. B. Adler. There are two full length chapters on the principles of transistors and transistor linear amplifiers that are models of lucid expository writing, and a pleasure to read. Although they are inserted in the plan of the book as chapters IV and V, they are essentially independent material, and can be read without reference to the rest of the text. In the later chapters sections on transistor applications in tuned amplifiers, power amplifiers, and oscillators, and on noise in transistors are inserted where appropriate.

The book which has resulted from the cooperation of these two authors is certainly a well balanced and useful addition to the engineering literature. A. C. BYERS

ENGINEERING ANALYSIS, by Stephen H. Crandall. 417 pages, diagrams, 6 × 9 in. New York, McGraw-Hill Book Co., Inc., 1956. Price, $9.50.

In order to utilize the marvelous new computing facilities now available to the

engineer, it is necessary to construct mathematical models and to reduce the resulting mathematical problems to numerical procedures. In his new book M.I.T.'s Professor Crandall recognizes the need for instruction in these endeavors.

With machine computation in mind, the steps required for the analysis of complex problems are illustrated. Most of the chapters begin with the statement of several representative problems. These statements are followed by a brief review of the classical mathematical theory involved, and here methods equivalent to the graduate engineering level are usually necessary. Numerical procedures pertinent to the particular problem are then demonstrated in sufficient detail to permit the student to undertake with considerable force the interesting extensions presented in the exercises.

Problems generally concerned with mechanics have been used by Professor Crandall, since his field is primarily mechanical engineering. Some are electrical problems. Among the mechanical examples are problems of equilibrium. For instance these may include a flexible beam subjected to a distributed load while resting on a continuous elastic foundation, or the steady state temperature distribution in a conducting slab when the temperatures along the edges are known.

The book reemphasizes the fact that many engineering problems share common mathematical methods of solution although their physical embodiments may be quite different. Of course this is an inexhaustible subject, and so it is only possible for Professor Crandall to acquaint the student with a kind of excellence which may be achieved in the treatment of analytical problems using modern computing methods.

This work will be of particular importance to engineering mathematicians, staff consultants, and those in charge of analysis groups to whom the more difficult problems are assigned. It would perhaps have been valuable to add a few more electrical problems in order to make the book easily adaptable to that field. As an introduction to Professor Crandall's text, the reviewer suggests a somewhat more elementary book on the subject which was published for John Wiley & Sons in 1954, "Engineering Analysis, An Introduction to Professional Method" by D. W. Ver Planck and B. R. Teare, Jr.

C. W. HARGENS

PUBLICATIONS RECEIVED

The Editors wish to call attention to these new books which have been received in the JOURNAL office for review. Lack of space prevents publication of full reviews.

REFERENCE DATA FOR RADIO ENGINEERS. Fourth edition, 1121 pages, illustrations, $5\frac{3}{4} \times 8\frac{1}{4}$ in. New York, International Telephone and Telegraph Corp., 1956. Price, $6.00.

THE TRUE BOOK ABOUT ATOMIC ENERGY, by E. C. Roberson. 142 pages, diagrams, $5 \times 7\frac{1}{4}$ in. New York, Philosophical Library, 1956. Price, $4.75.

Also the following 1956 republications by Dover Publications, Inc., of New York, of famous classics:

NUMERICAL INTEGRATION OF DIFFERENTIAL EQUATIONS, by Albert A. Bennett, William E. Milne and Harry Bateman. 108 pages, $5\frac{3}{8} \times 8$ in. Price, $1.35 (paper).

RAYLEIGH'S PRINCIPLE AND ITS APPLICATION TO ENGINEERING, by G. Temple and W. B. Bickley. 154 pages, $5\frac{3}{8} \times 8$ in. Price, $1.50 (paper).

THE ICOSAHEDRON AND THE SOLUTION OF EQUATIONS OF THE FIFTH DEGREE, by Felix Klein. 289 pages, $5\frac{3}{8} \times 8$ in. Price, $1.85 (paper).

TRIGONOMETRY REFRESHER FOR TECHNICAL MEN, by A. A. Klaf. 629 pages, $5\frac{3}{8} \times 8$ in. Price, $1.95 (paper).

CALCULUS REFRESHER FOR TECHNICAL MEN, by A. A. Klaf. 431 pages, $5\frac{3}{8} \times 8$ in. Price, $1.95 (paper).

MIND AND THE WORLD-ORDER, by Clarence Irving Lewis. 446 pages, $5\frac{3}{8} \times 8$ in. Price, $1.95 (paper).

BOOK NOTES

AMERICAN CIVIL ENGINEERING PRACTICE, edited by Robert W. Abbett. Volumes I and II. vp, diagrams, 5½ × 8¼ in. New York, John Wiley & Sons, Inc., 1956. Price, $15.00 each volume.

The present three-volume reference replaces "American Civil Engineers Handbook," first published in 1910 and edited by Merriman. The replacement is an entirely new, up-to-date reference, serving not only as a handbook, but presenting fundamental principles, procedures and techniques of the entire field of civil engineering. It is designed for use both by professional engineers and engineering students. Each of the three volumes covers one broad aspect of civil engineering and is complete in itself.

Volume I contains metropolitan and community planning, surveying, traffic, highways, airports, railroads, soil mechanics and site planning, foundations, earthwork, tunnels and mathematical tables. Volume II covers hydraulic, sanitary and harbor engineering. Volume III will contain masonry, reinforced concrete, steel and timber structures. Each volume has its own index and an ingenious device for locating sections (matching printed bars on the first page with similar ones printed at the beginning of each section).

Each of the thirty-four sections comprising the three volumes has been written by an expert and the whole has been skillfully edited by Robert W. Abbett. No civil engineer can afford to overlook this complete, authoritative work in stocking his library.

UNIT OPERATIONS OF CHEMICAL ENGINEERING, by Warren L. McCabe and Julian C. Smith. 945 pages, diagrams, 6 × 9 in. New York, McGraw-Hill Book Co., Inc., 1956. Price, $10.50.

This new undergraduate text for juniors and seniors assumes adequate preparation in mathematics, physics, chemistry and mechanics. The text is purposely long, to provide material either for a two-semester or a three-semester course. For the former, the teacher must make his own choice of topics to be omitted.

The text covers the standard material for such a course: fluid mechanics, size reduction, mixing, mechanical separations, heat flow, evaporation, gas absorption, distillation, leaching and extraction, crystallization, drying, etc. Space limitations have forced the omission of such topics as adsorption, dialysis, colloid milling, ion exchange, sublimation and other specialized methods.

Several appendices contain tables of various properties of liquids, gases and solids; an index completes the volume. Each chapter contains a list of references to recent literature and a list of problems.

ELEMENTS OF PURE AND APPLIED MATHEMATICS. 491 pages, 6 × 9 in. New York, McGraw-Hill Book Co., Inc., 1957. Price, $7.50.

The author of this new text is well qualified to select and present material in pure and applied mathematics, for he has taught college courses for sixteen years and he has also been associated with the Jet Propulsion Laboratory, the Naval Ordnance Laboratory and the Motorola Research Laboratory. He is able to judge from practical experience, what to teach students in the way of preparation for engineering careers.

Ten chapters, each independent of the others, cover linear equations, vector and tensor analysis, complex variables, differential equations, orthogonal polynomials, Fourier Series, Stieltjes Integrals, Laplace Transforms, calculus of variations, group theory, probability theory and statistics, and real-variable theory. Each section within each chapter has a few problems; there are numerous worked-out examples; and each chapter has a list of references.

CHEMICAL PROCESS ECONOMICS IN PRACTICE, edited by J. James Hur. 115 pages, diagrams, 5 × 7¼ in. New York, Reinhold Publishing Corp., 1956. Price, $3.75.

The latest addition to the "Experience in Industry" series published by Reinhold records the proceedings of the Fourth Symposium sponsored by the Philadelphia-Wilmington Section of the AICE and the School of Chemical Engineering, University of Pennsylvania.

In this small book, nine experts discuss

economics as related to chemical engineers. Their topics cover accounting procedures (and why they are necessary), plant investment, cost of services, plant operating costs, price of chemical products, economic analysis and financing the plant.

Practical aspects are emphasized, in down-to-earth language that will be appreciated both by student engineers and practicing engineers who hardly ever know as much as they should about the economics of the enterprise for which they work.

THE OSCILLOSCOPE AT WORK, by A. Haas and R. W. Hallows. Republication, 171 pages, illustrations, 5½ × 8½ in. New York, Philosophical Library, 1956. Price, $10.00.

This small book originally published in France, is a practical guide to the many applications of the cathode-ray oscilloscope. This English edition, considerably enlarged and revised by R. W. Hallows, will be welcomed by those interested in the various uses of the instrument. It is based on the theories and techniques accepted in Great Britain, and many of the excellent and numerous oscillograms are British additions to the original French version.

In addition to two introductory chapters on the general characteristics and measuring techniques, there are seven chapters devoted to special uses of the oscilloscope, including amplifiers, oscillators, rectifiers, modulators, circuits, etc. One chapter deals with operating troubles and one with recent improvements. The book is well illustrated with circuit diagrams and oscillograms.

THE CHEMISTRY AND TECHNOLOGY OF WAXES, by Albin H. Warth. Second edition, 940 pages, illustrations, 6 × 9 in. New York, Reinhold Publishing Corp., 1956. Price, $18.00.

In this second edition the author has tried to include all of the most important information on waxes published since the first edition in 1947. Generally, all of the chapters have been enlarged to include the latest pertinent references, and the appendices and tabulations have been added to where new information is available. Specifically, the section on uses of waxes has been made almost twice as large and the chapters on lipid waxes, microcrystalline or petroleum waxes, and the polyethylene waxes have also been greatly increased in size.

The author describes this edition as an up-to-date reference work for chemists and industrialists who must use waxes in their line of work, and as a text book for the student who wishes to enlarge his knowledge and background of a fascinating and not too well known or understood field. The goal of this second edition as well as the first has been the same, that is, to bring together and correlate the plethora of scattered information on waxes and present it in an easy to use ready-reference work. The extent to which the author has achieved his goal can be best seen from the wide acceptance and acclaim of his first edition and the enthusiastic support he has received for his second edition.

TRUXTON OF THE *CONSTELLATION*, by Eugene S. Ferguson. 307 pages, 5½ × 8 in. Baltimore, The Johns Hopkins Press, 1956. Price, $5.25.

Truxton was a picturesque old seadog who is best known for his heroic exploits in the *Constellation*, but there has been no full-scale biography of this early naval hero. The author of this dainty book does full justice in the various stages of his subject's career as merchant captain, privateersman, and naval commodore in a lively era. The story is told with due attention to historical accuracy. Especially interesting is the section devoted to the planning, building and out-fitting of the famous frigate in which Truxton made naval history. There are some finely etched vignettes of life in old Baltimore and Philadelphia. The bibliography furnishes the reader with an ample source of reference for a more extended study of the subject.

The book will appeal to every reader interested in the early days of the Navy and the man who gave it an enduring tradition of command, seamanship, and discipline.

AN ENCYCLOPAEDIA OF THE IRON & STEEL INDUSTRY, compiled by A. K. Osborne. 558 pages, 6 × 9½ in. New York, Philosophical Library, 1956. Price, $25.00.

Intended as a reference, this encyclopaedia will probably be limited to company purchases, since few individuals can afford to pay

$25 for a single book. The author intended the book to serve especially the smaller firms that cannot afford to maintain libraries. With this purpose in mind, the author has included concise descriptions of materials, plants, tools and processes, from preparation of the iron ore through to the finished product. Interspersed throughout the text are nine diagrammatic cross-section drawings of various equipment, and sixteen plates depicting some of the steps in steel-making and some of the effects of various treatments on the microstructure of the steel. The five appendices are valuable, since they include conversion tables, tables of weights and measures, properties of steels and effects of different treatments on plain carbon and alloy steels, signs and symbols, and a list of trade societies related to the Iron and Steel industries. The encyclopaedia covers the many advances made during the past thirty years in the iron and steel industries, and is a comprehensive, up-to-date reference work.

IRRATIONAL NUMBERS, by Ivan Niven. 164 pages, 5 × 7¼ in. New York, John Wiley & Sons, Inc., 1956. Price, $3.00.

This is the eleventh in the series of The Carus Mathematical Monographs and it is written by Ivan Niven, Professor of Mathematics at the University of Oregon. It maintains the high standards set by the previous monographs in the series. The monographs are aimed at presenting mathematical subjects in such a way that they can be understood by the educated layman as well as by scientists and other mathematicians. The author has carefully selected his material to emphasize number theory and Diophantine approximations, omitting the topological facets of the subject. The book is arranged so that the easier chapters are first, with each chapter independent of the others. The reader needs only elementary mathematics to read most of the book, although for parts of the material a knowledge of algebraic number theory and function theory is needed.

ORGANIC SYNTHESES. VOLUME 36, 1956. 120 pages, diagrams, 6 × 9 in. New York, John Wiley & Sons, Inc., 1956. Price, $3.75.

Volume 36 of this annual series presents 35 new methods for the preparation of organic chemicals. The chemicals discussed range from Bischloromethyl ether to 2,4,6-Tribromobenzoic acid and include, as usual, a section on "Procedure," one on "Notes," and the final section on "Methods of Preparation." Chemists have come to rely on this series to keep them up-to-date in their field.

MATHEMATICS MAGIC AND MYSTERY, by Martin Gardner. 176 pages, diagrams, 5⅜ × 8 in. New York, Dover Publications, Inc., 1956. Price, $1.00 (paper).

The nine chapters of this book provide enough "mathematical magic" to keep anyone busy and entertained for a long while. The author has drawn most of his material from personal contacts since the literature in the field is very scanty. As a result, the present book is the first attempt to cover the entire field of modern mathematical magic. The "tricks" are divided into six categories: tricks with cards (three chapters); magic with common objects such as dice, calendars, watches, dollar bills, matches and coins; "Topological Tomfoolery" which covers handkerchief tricks, string and rope tricks, clothing and rubber bands; tricks with special equipment; "Geometrical Vanishes" (two chapters); and magic with pure numbers. For anyone interested in mathematics or magic, this book will provide many a satisfying hour of recreation.

CURRENT TOPICS

Hydrogen and Oxygen in Germanium.—Germanium is so sensitive to the presence of impurities such as gallium or arsenic that a concentration of one part in ten billion is sufficient to produce a measurable change in its conductivity at room temperature. Since there are about 4.4×10^{22} germanium atoms per cubic centimeter, a concentration of the order of 10^{13} atoms of the impurity per cc. of germanium is significant.

The levels of impurity concentration often defy detection by the usual analytical procedures. Poorly identified impurities which cause resistivity changes in germanium as a result of heat treatment have been called "thermium"; poorly identified impurities which cause electron-hole lifetimes to diminish have been called "deathnium." It is significant, therefore, that other impurities present in amounts a hundred thousand times greater produce no known electrical effects. Two of these are hydrogen and oxygen which C. D. Thurmond, W. G. Guldner, and A. L. Beach of Bell Telephone Laboratories have recently found to occur in concentrations greater than 10^{18} atoms per cc.

Special samples of germanium were prepared for these studies by hydrogen reduction of pure germanium oxide in purified graphite crucibles. Single crystals were then grown from these samples from graphite crucibles under hydrogen, and one crystal was grown in a vacuum. Tests indicated that all of these crystals were n-type semiconductors with resistivities ranging from 1 to 10 ohmcentimeters. Lifetime of minority carriers was around 100 microseconds.

These crystals, as well as the polycrystalline germanium from which they were grown, were analyzed for hydrogen and oxygen by a refined vacuum fusion technique. The analysis showed no significant variations in hydrogen and oxygen content among the samples prepared under hydrogen, although results on the single crystals were more uniform. In these crystals the hydrogen content was 3 to 4×10^{18} atoms per cc. and the oxygen was between 1 and 2×10^{18} atoms per cc. For the crystal grown in vacuo, hydrogen was no greater than 1 to 2×10^{17} and oxygen about 6×10^{16} atoms per cc, less by a factor of about 15 than for those grown in hydrogen.

These results provide conclusive evidence that oxygen and hydrogen are both present in the interior of germanium single crystals. However, despite amounts greater than 10^{18} atoms per cc., the electronic states of these gases are such that neither holes nor electrons are contributed in adequate numbers to affect the conduction process in germanium. Since about twice as many hydrogen as oxygen atoms are present, it is possible that these two gases react in germanium and exist as water molecules, thus accounting, in part, for their electrical neutrality.

Remote-Controlled Microscope.—A new remote-controlled microscope developed by the General Electric Company at the Hanford plutonium plant inspects materials emitting radiation so intense that its optics eventually go "blind."

General Electric scientists use the

instrument to study changes that occur in the microstructure of metals exposed to chain-reaction bombardment. The information they gain is used to develop alloys and fabrication methods that will make atomic structures withstand increased radiation exposure.

Pieces examined in this work have been deformed by radiation and in the process have become ray emitters. As a result, the Hanford microscope is eventually damaged by these rays.

All work is done remotely inside the 38-ton steel cell which houses the radioactive sample. First, the sample is placed in the cell by means of mechanical "hands" powered by electric motors.

Such a "hand" removes the sample from a lead container and positions it against grinding and polishing wheels. Then, electrical etching equipment removes the top layer of metal which has been made into a "non-typical microstructure" by the heat of the grinding.

Mechanical "fingers" place the radioactive sample on the microscope stage, and the scientist manipulates sensitive controls to bring into focus one of three compound objective lenses.

Light beamed through a wall port is focused to a bright pin point, illuminating the polished sample of metal inside the cell. Reflected light from a circular dot of metal, sometimes as small as five one-thousandths of an inch in diameter, is collected by a compound lens and projected through another wall opening to an external eyepiece. There, it is transformed into a vastly enlarged image of the circular area.

The instrument can optically separate two elements of grain structure one one-thousandth of an inch apart. In effect, it places the observer's eye within one two-hundred and fiftieth of an inch of the "hot" surface and still permits the eye to focus.

Highly Efficient Generating Station.—The Philadelphia Electric Company is building an electrical generating station that will convert over 40 per cent of the heat contained in a pound of coal into electrical energy. That establishes an efficiency record—3 per cent more than any plant now in existence.

The new plant, which is expected to go into operation in 1959, is also record breaking in other respects. The boiler is designed to supply steam to its turbine generator at 5000 psi. pressure and 1200° F. Both of these values are the highest ever put to practical use. It has been only in recent years that alloys have been perfected which will withstand such temperatures and pressures at the same time.

Known as Unit No. 1 for Philadelphia Electric's new Eddystone plant, the boiler is of special design. Conventional designs depend on the bubbling action of boiling water to produce circulation within a boiler. But, because this bubbling action does not take place at extremely high pressures, circulation in PE's boiler must be achieved through pumping.

Called a once-through boiler, the unit consists of 150 miles of 1½-in. tubing. To generate this steam, two railroad carloads of powdered coal an hour will be blown into the 100-ft. high furnace.

The design of this tomorrow's plant, so far ahead of practical experience, entailed many problems which were explained to engineers attending the annual meeting of The American Society of Mechanical Engineers. The job is of such magnitude that it is being handled by a com-

mittee of project engineers composed of men assigned by the utility and the several manufacturers. As the work progresses and problems are encountered, this committee is supplemented by other sub-committees experienced in special phases of the work.

Cotton Carpeting Cleaned in Place.—Rug-cleaning firms who have had difficulties with cotton carpeting can now obtain an answer to some of their problems. A satisfactory method of thoroughly cleaning this type of carpeting on the floor has been developed under supervision of the U. S. Department of Agriculture; and it is expected that the findings will prove valuable to rug-cleaning firms throughout the country. The method and a special machine for the purpose were developed by the Hoover Company of North Canton, Ohio, under contract with the Southern Utilization Research Branch of the Agricultural Research Service, USDA, the Department's big cotton utilization research center in New Orleans, La.

The new system eliminates the overwetting and browning which caused trouble with ordinary methods, and provides for quick drying and restoration of the pile. Large quantities of fresh suds are applied to the carpet through the center of a rotating brush, the suds worked outward through the carpet pile and then sucked up through a vacuum nozzle surrounding the brush. Thus suds and soil are removed quickly. Silica gel laid over the carpet between layers of cotton batiste then quickly takes up most of the moisture.

Details of this new method for cleaning cotton carpeting can be obtained without cost from theSouthern Utilization Research Branch, 1100 Robt. E. Lee Blvd., New Orleans 19, La.

Better Enlargements from "Miniature" Negatives.—A famed scientist's hobby-inspired idea for making better enlargements from 35-mm. negatives became available to photographers when Simmon Brothers, Inc., of Long Island City, N. Y., begins marketing the "Refractamatic 35" and "Refractasil."

The effects of scratches, dust, and oily fingerprints are corrected in enlargements made by the new technique, which was developed by Dr. C. G. Suits, General Electric vice president and director of research.

"Refractamatic 35" is a special negative holder designed for use in the Simmon Omega enlarger; it permits the negative to be completely immersed in "Refractasil," a unique silicone liquid. Together, the two products reflect the results of Dr. Suits' scientific attack on a problem that had long plagued him and other miniature camera fans—scratches on negatives that otherwise would produce salon-quality prints.

Through analysis of film scratches, Dr. Suits found that most of the damage occurred not in the silver image itself but in the film base or the gelatine coating over the emulsion. A scratch on the silver image results in a black line on the final enlargement. This situation is irreparable except by tedious hand work on the print. Scratches in the base or overcoat, however, are much more common. These produce white lines on the print because the "valleys" of the scratches scatter the light projected through the negative when enlargements are made, leaving corresponding unexposed lines on the enlarging paper.

For many years, fastidious photographers have used glycerine or some kind of transparent grease to fill these valleys. Because of viscosity, tend-

ency to form bubbles, and difficult removal after use, these remedies frequently were more troublesome than the original problem they were meant to solve.

Dr. Suits recognized that to do its primary job of removing the effects of scratches, the liquid must have exactly the same index of refraction as the film base. Thus the scratches would be filled and there would be no bending of light rays at the surface between the film and the liquid.

The liquid also had to be nearly water-white, non-toxic, inert to film and emulsion, odorless, of proper viscosity, and possessing just the right vapor-pressure—neither so high that it would vaporize rapidly when in use, nor so low that it would not evaporate promptly when wiped off after use.

The specifications seemed formidable. Water itself softens the film gelatine and can be a source of additional difficulties. Glycerine was discarded because of its viscosity, the bubble problem, and the damage it does to negatives. Carbon tetrachloride has the proper refractive index and fulfills some other requirements, but evaporates too rapidly and is definitely toxic if used in a closed room.

Dr. Suits experimented with a long list of compounds that appeared hopeful before his quest eventually led to an unusual member of a comparatively new family of compounds known as silicones. In recent years, silicone oils, gums, and rubbers have become famous by solving problems ranging from high- and low-temperature gaskets for aircraft to waterproofing on suede jackets. Silicone oils help bread and tires pop from their molds, make concrete highways less slippery, and are used in hundreds of other new applications.

Certain silicone oils seemed to fit all of the specifications Dr. Suits had listed—with an added bonus. Early tests disclosed that the liquid finally selected, and named "Refractasil," could be wiped off easily, leaving the negative not only dry but exceptionally clean. It removed oily fingerprints and, in the special film holder devised by Dr. Suits, did a fine job of getting rid of dust.

In the "Refractamatic 35," each frame of the 35-mm. film is bathed thoroughly on both sides merely by squeezing a bulb. Loose dust particles are flushed out and disappear. The "Refractasil" is kept clear by a small filter built into the negative holder.

Use of the "Refractamatic 35" and "Refractasil" greatly reduces the exceptional precautions that traditionally surround the handling of 35-mm. film. Any handling procedure that does not actually gouge the silver layer can be tolerated, since ordinary scratches, cinch marks from rolling the film tightly, and fingerprints will not show up on the finished print.

After the negative is removed from the holder, it should be wiped with a chamois or hand tissue to remove excess liquid. This leaves it perfectly dry and exceptionally clean.

Simmon Brothers, Inc., have now adapted the original Suits' model and produced a commercial version of the "Refractamatic 35" incorporating all of the features needed for use by professionals and advanced amateurs. The holder is easy to use, permits the film to be held rigidly in the focal plane of the enlarger lens while it is at the same time completely immersed in the liquid, and has a built-in circulating and filtering system. "Refractasil," which is being produced by General Electric's Silicone Products Department at Waterford, N. Y., is also marketed by Simmon Brothers, Inc.

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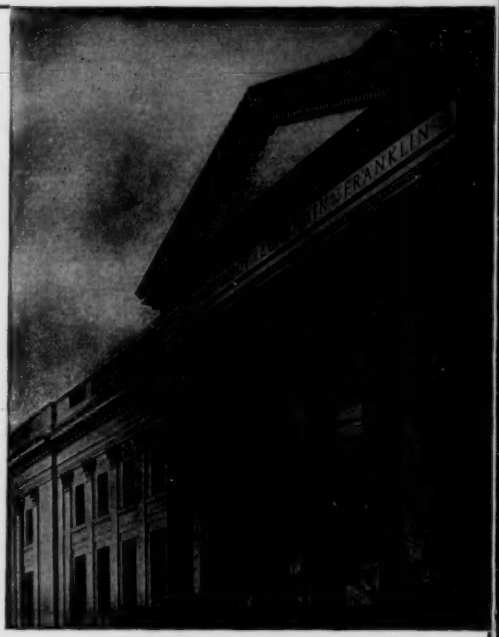

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